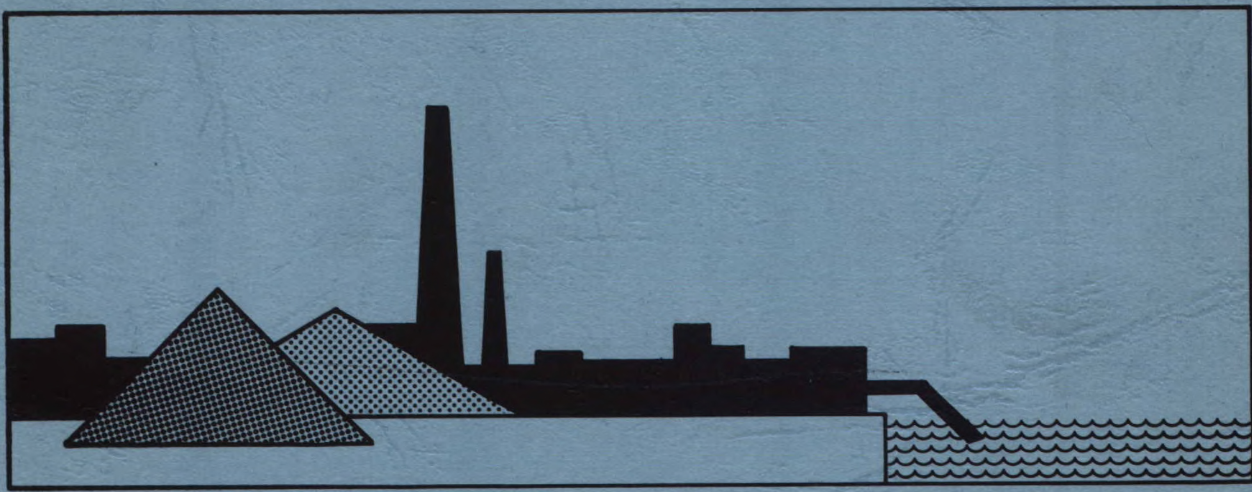
Environment Canada
Inland Waters Directorate
executed for
Energy Mines and Resources, Canada



# Water Supply Constraints to Energy Development - Phase II

## Summary Report

May 1983



Acres Consulting Services Limited

Environment Canada
Inland Waters Directorate
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Energy Mines and Resources, Canada

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# 1 - INTRODUCTION

The federal government in cooperation with provincial governments has a responsibility to maintain a reconnaissance on the water availability in the different regions in the country vis-à-vis the current and potential future requirements for the water. Also, in negotiating international water agreements it must ensure that the long-term water requirements of Canadians are met.

A current thrust of federal policy is to increase the production of fossil fuels within Canada. Emphasis is being placed on the development of sources such as the tar sands where the water demand for separation and processing per unit output is very high. Development of the major projects envisaged in the National Energy Plan, therefore, adds a substantial demand to existing uses. Because of the capital-intensive nature of many of the projects being considered, these new demands will have to receive a very high priority during water short periods.

At the same time as water use requirements for energy-related projects are increasing, other developments--both municipal and industrial--will grow at a pace matching growth in the energy sector. These too, will cause increased need for water. Also, in much of the Prairie area, there is a substantial potential for additional irrigation typically withdrawing from some of the sources that would be used for supplying energy developments or meeting needs generated by the economic activities flowing from these developments. This is particularly true in the Prairie region where significant increases in energy developments and other water uses, in particular agricultural water use, is causing intense competition for the available water resource in an area which is generally short of water.

These facts have pointed to a need to develop a planning tool which will forecast future water needs from a multisectoral assessment. The Inland Waters Directorate sponsored by the Department of Energy, Mines and Resources has initiated a multiphase study to develop such a planning tool.

Phase I, an overview study of basic data identifying regions where water use constraints are likely to occur, has been completed and the results are documented (Water Supply Constraints to Energy Development, Phase I, 1982). The report forms a comprehensive background document of proposed energy developments in Canada for the period 1981 to 2002. It identifies areas likely to come under increasing water stress over the next few years based on a single projection of water uses. There was a need identified to develop a planning tool which would permit the examination of the water use of a large variety of development scenarios.

Phase II, which is reported herein, develops the basic water use model and tests it using data from the South Saskatchewan River Basin.

The water use model draws from demand data bases including population forecasts and agricultural and industrial development to forecast water requirements by river basin. These forecasts are compared with water availability generated from naturalized streamflow records to assess long-term potential water use problems.

Two rather clear criteria have been kept in mind during the development of the simulation model.

- The primary use of the model is directed at the study of water availability for the energy sector. Notwithstanding this, every effort has been made to produce a balanced model which considers all water uses as, quite obviously, any additional consumptive use in another sector will impact use in the energy sector.

- The model has been structured so that individual components of it (such as water use for agriculture) can be developed in more detail once funds are available for such development.

This report is intended to summarize the basic concepts and structure of the model, applications where it might be used and hardware and software requirements for its use. The test case has been prepared to demonstrate the use of the model and to test the relative impacts of various water use parameters. The South Saskatchewan River Basin was selected for study in the test case as it is among the regions of the country with the most critical water shortages.

A companion document, "Water Use Forecasting Model - User's Manual", provides specific details on how to run the model.

## 2 - CONCEPT OF THE WATER MANAGEMENT MODEL

The basic purpose of the model is to compare forecasted water use requirements with available supply to identify those basins and subbasins which have potential water shortages. The smallest element examined is the subbasin, typically a tributary or segment of a major river system, which has a stream "gauge point" associated with it. The results of the subbasin analysis are aggregated to produce results by major river basin and by province or economic region. The economic regions used in the model are the five regions used by Statistics Canada (Statscan): Atlantic, Quebec, Ontario, the Prairies and British Columbia.

The model may be considered as a 3-step process.

### Step 1

Determine the water use requirements of each subbasin. Water use data include both gross intake and consumptive use. Gross intake includes all water abstracted from the stream and groundwater system within the subbasin whether or not the water is returned to the subbasin. Consumptive use is that water abstracted and not returned to the subbasin. Data files are prepared by the user containing base year information relating to population, agricultural and industrial development, as well as the water use rates for each of these categories. Forecast files are also prepared by the user describing the rate of growth anticipated in each category. Minimum flows can be specified at the outlets to each subbasin to reflect water quality and recreational water use requirements within the subbasin.

Step 2

Determine water availability. For each subbasin, a sequence of naturalized monthly hydrologic records is prepared and filed with the model.

Step 3

Compare water use and availability. For the demand forecast year selected by the user, the model determines the water intake and consumption requirements and compares these month by month against the naturalized hydrologic record of the subbasin. Statistics relating the gross intake and consumption to water availability are produced.

These three steps are defined in more detail below.

## 2.1 - Water Use Requirements

Water use is determined within three basic categories: agricultural, municipal and industrial. The data required by the model to determine the water use by each of these three categories are discussed below.

### 2.1.1 - Agricultural

Water use for the agricultural component is expressed as gross intake and consumption in cubic metres per hectare per year for a variety of irrigated crops. These demands are distributed over the year using monthly distribution factors corresponding to the cropping calendar. Livestock total intake water requirements are expressed in litres per head per day and consumption is expressed as a percentage of the total intake. Water use rates per head or per hectare must be determined by the user on the basis of published data or discussions with irrigation agencies.

Data files containing the base year agricultural data expressed as total irrigated area by crop and number of head by livestock type must be prepared for each subbasin by the user. Data are available for the 1981 census from Statscan, however, only total irrigated area for all crops is reported. Other sources and assumptions must, therefore, be used regarding the irrigated area of each crop type.

Forecasts of agricultural development (including irrigated crops and livestock) must be prepared by the user from documented forecasts or on the basis of past trends.

The model uses the agricultural water use rates and the forecasts of agricultural development to compute the total agricultural water requirements in the subbasin.

Agricultural water uses, particularly in terms of intake and consumptive use for irrigated crops, are among the least accurate estimates made in using the model in its current form. Agricultural water use rates are highly variable from area to area and from year to year due to differences in precipitation, evapotranspiration, irrigation method and, of course, crop type. In order to make reasonably accurate estimates of irrigation water requirements in the subbasin, data on demands must be available for that particular subbasin. In the future, the model would be enhanced by including a subroutine which calculates water requirements based on meteorologic and cropped area data.

### 2.1.2 - Municipal

Municipal water use in the model is expressed as litres per capita per day for both rural and urban populations. Within each of these two categories it is possible to specify the percentage of per capita demand contributed by residential, commercial and public sectors.

The per capita water use must be supplied by the user. Provincial data are available from the Canada Water Year Books produced by Environment Canada (Environment Canada, 1976). For specific subbasins it may be possible to obtain more accurate data from other published sources or from the largest municipality in the subbasin. It is important that industrial water requirements, supplied through the municipal distribution system, be eliminated from the reported municipal requirements. Industrial water use is accounted for separately in the model.

Population data, split into rural and urban components, are available for each subbasin from Statscan based on the 1981 census. These data are also supplied to the model by the user. Statscan also can provide forecast population growths by province under various development scenarios which are apportioned to the subbasin on the basis of baseline population data.

The model uses the municipal water use rates and the forecasts of future population to establish the total municipal requirement in each subbasin.

### 2.1.3 - Industrial

Industrial water use is categorized into the 30 basic industrial sectors listed in Table 2.1. Some of these sectors

TABLE 2.1

LIST OF INDUSTRIAL SECTORS

| Number | Basic Sector | Number | Detailed Sector |
|---|---|---|---|
| 1 | Agriculture | 1 | Agriculture |
| 2 | Forestry | 2 | Forestry |
| 3 | Metal mines | 3 | Metal mines |
| 4 | Mineral fuels | 4 | Fuels, oil and gas |
| | | 5 | Fuels, coal |
| 5 | Nonmetal mines | 6 | Nonmetal mines |
| 6 | Food and beverages | 7 | Food and beverages |
| 7 | Tobacco | 8 | Tobacco |
| 8 | Rubber and plastics | 9 | Rubber |
| | | 10 | Plastics |
| 9 | Leather | 11 | Leather |
| 10 | Textiles | 12 | Textiles |
| 11 | Wood | 13 | Wood |
| 12 | Furniture | 14 | Furniture |
| 13 | Paper | 15 | Paper, mills |
| | | 16 | Paper, finishing |
| 14 | Printing | 17 | Printing |
| 15 | Primary metals, iron | 18 | Iron, mills |
| | | 19 | Iron, foundries |
| 16 | Primary metals, other | 20 | Other, smelting |
| | | 21 | Other, extruding |
| 17 | Metal fabricating | 22 | Metal fabricating |
| 18 | Machinery | 23 | Machinery |
| 19 | Transportation equipment | 24 | Transportation equipment |
| 20 | Electrical products | 25 | Electrical products |
| 21 | Nonmetallic minerals | 26 | Nonmetallic minerals |
| 22 | Petroleum and coal | 27 | Petroleum refineries |
| | | 28 | Petroleum and coal products |
| 23 | Chemicals | 29 | Chemicals, industrial |
| | | 30 | Chemicals, other |
| 24 | Miscellaneous manufacturing | 31 | Miscellaneous manufacturing |
| 25 | Construction | 32 | Construction |
| 26 | Transportation | 33 | Transportation |
| 27 | Electric power | 34 | Electric power |
| 28 | Other utilities | 35 | Other utilities |
| 29 | Trade | 36 | Trade |
| 30 | Other | 37 | Other |

Note: Although the agricultural sector is included in the list, all calculations for agricultural water use are done separately based on specific irrigation figures, not on an economic basis. The purpose of including agriculture in the list of industrial sectors is to ensure any economic growth in agriculture is properly reflected in the growth of other sectors through application of the intra-regional input/output matrices (see Section 3.1.7).

have been further subdivided to provide a better representation of water use. In total, 37 sectors have been categorized and these are also listed in Table 2.1.

Energy-related developments have been classified under the industrial sector in the following categories:

| | |
|---|---|
| - mineral fuels | - fuels, oil and gas |
| | - fuels, coal |
| - petroleum and coal | - petroleum refineries |
| | - petroleum and coal products |
| - electric power | - electric power. |

This breakdown is sufficient for describing existing systems, although in future a further breakdown of various types of generating plants would be useful. When new energy-related developments are forecast, their specific water use rates are input directly in the model.

The basic unit used in the model to gauge industrial activity is the dollar output of the sector (always expressed in terms of 1981 dollars). The total water intake and consumptive use of each of the 37 industries is therefore expressed in litres per annual 1981 dollars of industrial output. The model computes future water use (both intake and consumption) from forecasts of real growth in each industrial sector, the growth being expressed in 1981 dollars.

To use the model, the user must therefore supply

- industrial water use coefficients for gross intake and consumption

- the base year value of output (shipments) by industrial sector for each economic region in Canada (British Columbia, Prairies, Ontario, Quebec, Atlantic)

- the proportion of the total economic region output of the industrial sector which is contributed by the subbasin

- forecasts of industrial growth by sector.

Water use coefficients relating the values of shipments in 1981 dollars to actual water use by industry have been developed in this study from relating the projected national water demands for 1981 with the national value of shipments. Details are provided in Appendix B. These can be modified if specific industrial water use data are available for the subbasin. The year 1981 has been used as a base year in the test case evaluations since data from the 1981 census are applicable without adjustment. Any other base year may be selected as long as all data are related to that particular year.

Although it would be most efficient to have Statscan supply the 1981 dollar output by industry in each subbasin in order to determine the proportion of that sector in each subbasin, this information is often kept confidential. Statscan has provided for the test case, however, the number of employees in each industry by subbasin. Using the economic region value of shipments and total labor force by industry, it has therefore been possible to estimate the percent contribution of each subbasin to the total value of shipments of the economic region.

The model incorporates industrial input/output matrices for each economic region in order to correctly maintain the backward and forward production linkages between various industries. Similarly, the interregional trade estimates for the 37 sectors, as produced by Statscan, have also been included. Therefore, the impact of growth in one sector in one economic region is reflected in the growth of that sector in another economic region.

Various options for forecasting industrial growth (as described in Section 3.1.3) are available to the user; however, the primary mechanism is expected to be a forecast of increase in output using annual growth rates for each sector. The subbasin increase in output for each sector can be based on the historic proportion of value of shipments from the subbasin as previously determined from an evaluation of labor force data.

The model combines the forecasts of value of shipments with the water use coefficients to establish the total volume of water required by industries in the subbasin.

### 2.1.4 - Minimum Flow Constraints

In many subbasins, a minimum flow is required to satisfy recreation or water quality constraints. The model provides the user with the option of specifying this minimum flow at the outlet to the subbasin. The model computes the outflow considering subbasin inflows and consumptive uses. Months when the minimum flow constraint is violated are flagged in the output and their frequency of occurrence is documented.

## 2.2 - Water Availability

Normally, water availability is determined from a stream gauge corresponding to the outflow location of a subbasin. Monthly hydrologic data should be naturalized by removing the historic effects of agricultural, municipal and industrial water use. In its current format, the model requires that the effects of upstream reservoir regulation are included in the supplied hydrology. In future, a mechanism for simulating reservoir operation would be a worthwhile feature of the model.

Provision has also been made in the model for including groundwater as a direct supply to the subbasin. The inflows are expressed in million cubic metres per month. At this stage of model development, specific aquifers and their limitations, maximum withdrawal and recharge rates have not been included. A submodel of these components will be considered during future development of the model.

It is also possible to simulate the transfer of water from one subbasin to another or from outside the major basin under study. This enables the user to study the effects of a diversion on satisfying needs in water short areas.

## 2.3 - Comparison of Water Supply and Use

Water supply and use are compared monthly over the period of available hydrologic record by calculating the ratio of water use to supply for each month. A frequency histogram of these ratios is produced and the months with the most critical (highest) ratio of use to supply is identified.

In setting up the model, the user specifies the hierarchical relationship of the subbasins within a main basin. The model examines the upstream subbasins first, passing surplus water to the next subbasin downstream. Local inflows to the subbasin under consideration, diversions and surplus flows from upstream are considered in computing water availability. In this way, the impacts of all upstream water sources and water uses are accounted for in analyzing downstream basins. Final results may be aggregated by subbasin, basin, province or economic region.

## 2.4 - Applications of the Model

The model has been designed to enable the user to ask a wide range of "what if" questions relating multisectoral growth to the availability of water. The model can also be used to make a preliminary assessment of various remedial measures (such as diversions) envisaged to relieve areas with chronic water shortages. The following specific applications are observed.

(a) Primary application of the model is expected to be in the evaluation of water resource impacts of adding new energy-related developments to specific river basins. The model has been designed for this type of site-specific evaluation, and guidelines to the water use rates for various forms of energy developments are presented in Appendix C.

(b) The model may be used to make preliminary evaluation of the impact of developments or growths in different sectors on various international or provincial apportionment agreements. A node would be located at the boundary and a minimum flow in each month would be specified. The model would record the number of violations of this minimum flow. Future development of the model should consider an option of expressing the minimum flow constraint as a percentage of the naturalized historic streamflow.

(c) By changing the development forecasts, the impact of various growth scenarios on potential water shortage areas can be examined. The exogenous forecasts for each industrial sector are input by economic region. Therefore, the impact of industrial growth in one region can be studied in light of its effect within the same region and, through the interregional input/output matrices, on the other economic regions in the country. Similarly, the effects of change in one industrial sector or other industrial sectors in the region can be studied using the intraregional input/output matrices.

(d) Population and agricultural forecasts can be altered to examine their impact on overall water availability and, hence, on water available to industry.

(e) The range of coefficients relating industrial water use to value of outputs in dollars has been developed from an examination of past trends as discussed in Appendix B. If the user wishes to examine the impact of an envisaged technological change, the range of the appropriate water use coefficients can be altered.

(f) Interbasin transfers can be simulated with the model and therefore the impact of planned diversion schemes on water shortage problems can be judged.

(g) The impact of additional on-stream storage on water shortages can be judged. Although the model does not currently simulate reservoir operation, the user may examine the sequence of water deficits and surpluses at a given location using mass balancing techniques. The impact of additional storage in alleviating the deficits can then be determined.

(h) Studies have and will continue to be conducted on medium- and long-term climatic changes in Canada and around the world. With the implementation of an agricultural submodel, it will be possible to evaluate the impact of forecasted climatological changes on crop water requirements and hence on overall water resource utilization.

# 3 - WATER USE FORECASTING MODEL

This section of the report provides a full description of the structure, basic data and assumptions inherent in the model. Detailed instructions on its use are not included here but can be found in the companion document "Water Use Forecasting Model - User's Manual."

## 3.1 - Data Files

The most understandable way of describing the model is with reference to the files and calculation modules which form its structure. This structure is illustrated in Figure 3.1 and the individual files are discussed below.

### 3.1.1 - Data Base File

This file contains information which would not normally be changed from one run to the next such as base economic year, provincial and regional nomenclature, etc. The most significant information contained in this file is the coefficient data for the industrial, agricultural and municipal water uses. A sample listing of the file, for reference in the following discussion, is presented in Tables 3.1 to 3.5.

(a) Industrial Water Use Coefficients

As noted in Section 2.1.3, industrial water use by sector for both gross intake and consumption has been related to the dollar value of shipments by that sector within the economic region. The 1981 water use coefficients have been determined from data available for

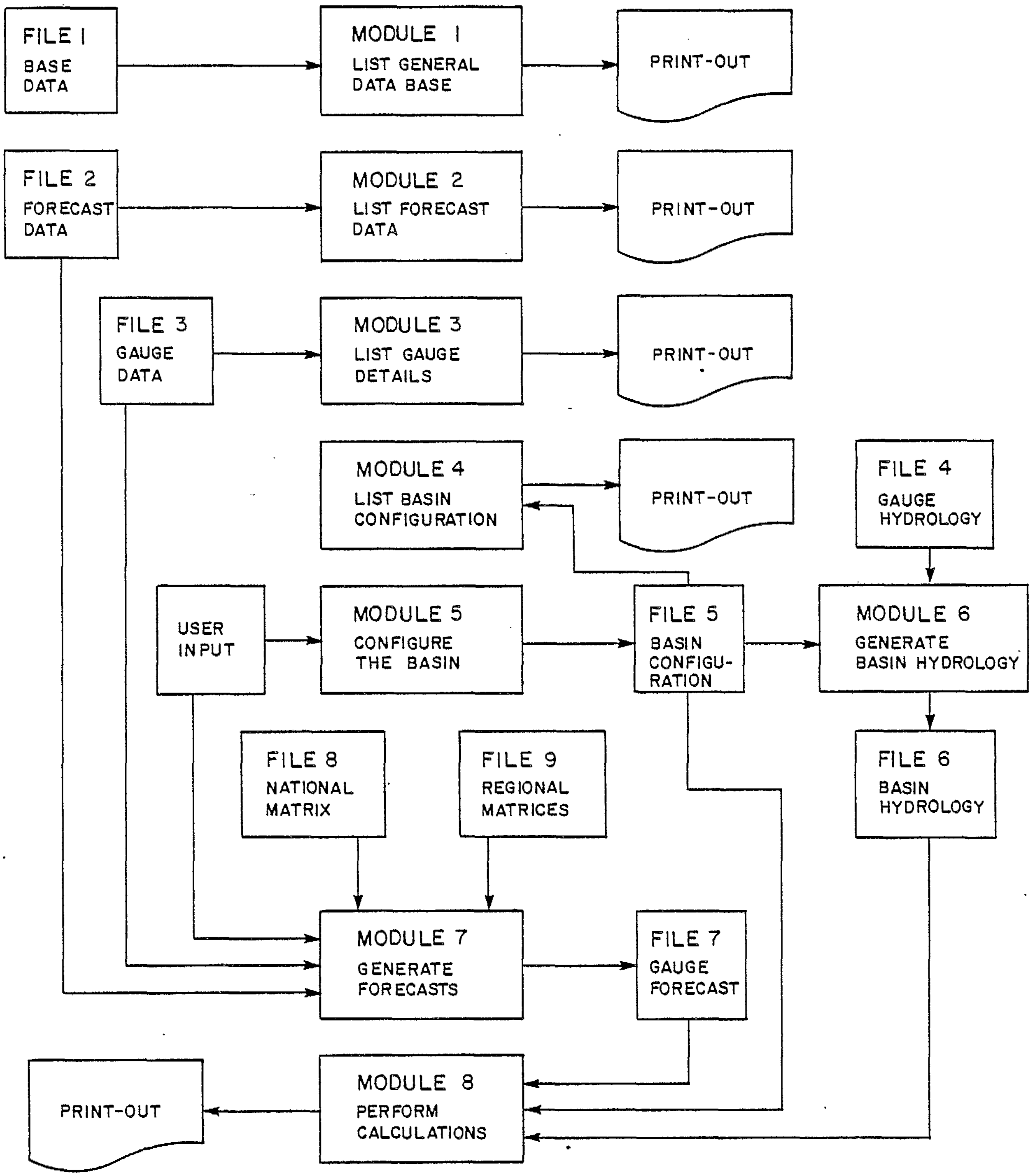



FIG. 3.1

WATER MANAGEMENT MODEL STRUCTURE

ACRES

TABLE 3.1

DATA BASE FILE
BASIC DATA

| Month | Name | Days |
|---|---|---|
| 1 | Jan. | 31 |
| 2 | Feb. | 28 |
| 3 | March | 31 |
| 4 | April | 30 |
| 5 | May | 31 |
| 6 | June | 30 |
| 7 | July | 31 |
| 8 | Aug. | 31 |
| 9 | Sept. | 30 |
| 10 | Oct. | 31 |
| 11 | Nov. | 30 |
| 12 | Dec. | 31 |

| Region | Name |
|---|---|
| 1 | BC |
| 2 | Prairies |
| 3 | Ontario |
| 4 | Quebec |
| 5 | Maritime |

| Prov. | Name | Region |
|---|---|---|
| 1 | B. C. | BC |
| 2 | Alberta | Prairies |
| 3 | Saskatchewan | Prairies |
| 4 | Manitoba | Prairies |

TABLE 3.2

DATA BASE FILE
1981 REGIONAL ECONOMIC OUTPUT
BY INDUSTRIAL SECTOR

| | | Final Demand (Million $) | | | | |
|---|---|---|---|---|---|---|
| Sector | Name | BC | Prairies | Ontario | Quebec | Maritime |
| 1 | Agriculture | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | Forestry, etc. | 2659.9 | 170.4 | 0.0 | 0.0 | 0.0 |
| 3 | Metal Mines | 1337.7 | 842.7 | 0.0 | 0.0 | 0.0 |
| 4 | Fuels, Oil & Gas | 794.2 | 23942.0 | 0.0 | 0.0 | 0.0 |
| 5 | Fuels, Coal | 522.4 | 374.7 | 0.0 | 0.0 | 0.0 |
| 6 | Non-Metal Mines | 46.3 | 966.9 | 0.0 | 0.0 | 0.0 |
| 7 | Food & Beverages | 2919.9 | 6302.8 | 0.0 | 0.0 | 0.0 |
| 8 | Tobacco | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 | Rubber | 66.6 | 85.9 | 0.0 | 0.0 | 0.0 |
| 10 | Plastics | 66.6 | 128.9 | 0.0 | 0.0 | 0.0 |
| 11 | Leather | 16.0 | 23.4 | 0.0 | 0.0 | 0.0 |
| 12 | Textiles | 180.3 | 526.5 | 0.0 | 0.0 | 0.0 |
| 13 | Wood | 4633.5 | 697.3 | 0.0 | 0.0 | 0.0 |
| 14 | Furniture | 121.0 | 245.9 | 0.0 | 0.0 | 0.0 |
| 15 | Paper, Mills | 3266.4 | 287.8 | 0.0 | 0.0 | 0.0 |
| 16 | Paper, Finishing | 285.6 | 455.1 | 0.0 | 0.0 | 0.0 |
| 17 | Printing | 458.4 | 774.5 | 0.0 | 0.0 | 0.0 |
| 18 | Iron, Mills | 55.8 | 463.1 | 0.0 | 0.0 | 0.0 |
| 19 | Iron, Foundries | 50.5 | 555.4 | 0.0 | 0.0 | 0.0 |
| 20 | Other, Smelting | 680.6 | 391.5 | 0.0 | 0.0 | 0.0 |
| 21 | Other, Extruding | 165.3 | 55.4 | 0.0 | 0.0 | 0.0 |
| 22 | Metal Fabricating | 1017.7 | 1399.0 | 0.0 | 0.0 | 0.0 |
| 23 | Machinery | 576.3 | 1280.3 | 0.0 | 0.0 | 0.0 |
| 24 | Trans. Equipment | 806.8 | 678.5 | 0.0 | 0.0 | 0.0 |
| 25 | Electric Products | 215.1 | 372.7 | 0.0 | 0.0 | 0.0 |
| 26 | Non-Metal Mineral | 542.8 | 1037.1 | 0.0 | 0.0 | 0.0 |
| 27 | Petrol Refineries | 1802.0 | 3377.2 | 0.0 | 0.0 | 0.0 |
| 28 | Petroleum & Coal | 13.6 | 61.4 | 0.0 | 0.0 | 0.0 |
| 29 | Chemicals, Indust | 302.1 | 1215.7 | 0.0 | 0.0 | 0.0 |
| 30 | Chemicals, Other | 269.3 | 351.0 | 0.0 | 0.0 | 0.0 |
| 31 | Misc. Manufacture | 124.6 | 193.9 | 0.0 | 0.0 | 0.0 |
| 32 | Construction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 33 | Transportation | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 34 | Electric Power | 886.2 | 1408.8 | 0.0 | 0.0 | 0.0 |
| 35 | Other Utilities | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 36 | Trade | 23573.8 | 36509.5 | 0.0 | 0.0 | 0.0 |
| 37 | Other | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

TABLE 3.3

DATA BASE FILE
SAMPLE INDUSTRIAL WATER USE
COEFFICIENT

| Sector | Name | Matrix Index | Recirc Factor | % Lost | Water Intake Scenarios MCM/year/$M | | |
|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 |
| 1 | Agriculture | 1 | 1.00 | 0.0 | 0.00000 | 0.00000 | 0.00000 |
| 2 | Forestry, etc. | 2 | 2.59 | 75.0 | 0.71500 | 0.79300 | 0.87100 |
| 3 | Metal Mines | 3 | 3.66 | 94.0 | 0.06900 | 0.07612 | 0.08379 |
| 4 | Fuels, Oil & Gas | 4 | 2.62 | 77.4 | 0.00411 | 0.00460 | 0.00512 |
| 5 | Fuels, Coal | 4 | 2.64 | 90.7 | 0.00505 | 0.00572 | 0.00674 |
| 6 | Non-Metal Mines | 5 | 2.24 | 22.4 | 0.08746 | 0.09817 | 0.11244 |
| 7 | Food & Beverages | 6 | 1.42 | 8.1 | 0.01344 | 0.01496 | 0.01648 |
| 8 | Tobacco | 7 | 6.36 | 24.2 | 0.00093 | 0.00109 | 0.00126 |
| 9 | Rubber | 8 | 1.31 | 0.8 | 0.13065 | 0.14318 | 0.15750 |
| 10 | Plastics | 8 | 1.31 | 0.7 | 0.19507 | 0.21203 | 0.23238 |
| 11 | Leather | 9 | 1.10 | 6.9 | 0.00373 | 0.00397 | 0.00421 |
| 12 | Textiles | 10 | 1.71 | 5.3 | 0.01226 | 0.01437 | 0.01606 |
| 13 | Wood | 11 | 1.48 | 2.6 | 0.04052 | 0.04468 | 0.04936 |
| 14 | Furniture | 12 | 1.40 | 28.6 | 0.00065 | 0.00072 | 0.00078 |
| 15 | Paper, Mills | 13 | 3.13 | 3.7 | 0.25452 | 0.28385 | 0.31245 |
| 16 | Paper, Finishing | 13 | 3.10 | 3.6 | 0.10169 | 0.11035 | 0.11900 |
| 17 | Printing | 14 | 12.81 | 2.9 | 0.00087 | 0.00097 | 0.00109 |
| 18 | Iron, Mills | 15 | 2.50 | 4.2 | 0.10739 | 0.11988 | 0.13236 |
| 19 | Iron, Foundries | 15 | 2.50 | 4.0 | 0.09928 | 0.10973 | 0.12018 |
| 20 | Other, Smelting | 16 | 1.62 | 3.2 | 0.18789 | 0.21023 | 0.23156 |
| 21 | Other, Extruding | 16 | 1.63 | 3.3 | 0.15508 | 0.17059 | 0.18998 |
| 22 | Metal Fabricating | 17 | 2.22 | 3.8 | 0.00355 | 0.00420 | 0.00452 |
| 23 | Machinery | 18 | 1.78 | 61.3 | 0.00165 | 0.00183 | 0.00200 |
| 24 | Trans. Equipment | 19 | 1.50 | 0.4 | 0.01726 | 0.01899 | 0.02040 |
| 25 | Electric Products | 20 | 2.72 | 2.3 | 0.00588 | 0.00625 | 0.00671 |
| 26 | Non-Metal Mineral | 21 | 1.92 | 9.9 | 0.03047 | 0.03390 | 0.03916 |
| 27 | Petrol Refineries | 22 | 2.14 | 5.1 | 0.04620 | 0.05104 | 0.05654 |
| 28 | Petroleum & Coal | 22 | 2.13 | 5.1 | 0.81177 | 0.89836 | 0.98134 |
| 29 | Chemicals, Indust | 23 | 2.20 | 6.3 | 0.12063 | 0.13372 | 0.14544 |
| 30 | Chemicals, Other | 23 | 2.20 | 6.3 | 0.19853 | 0.22153 | 0.24582 |
| 31 | Misc. Manufacture | 24 | 2.10 | 11.0 | 0.00380 | 0.00424 | 0.00460 |
| 32 | Construction | 25 | 1.00 | 0.0 | 0.00000 | 0.00000 | 0.00000 |
| 33 | Transportation | 26 | 1.00 | 0.0 | 0.00000 | 0.00000 | 0.00000 |
| 34 | Electric Power | 27 | 1.00 | 1.1 | 1.43936 | 1.59819 | 1.73717 |
| 35 | Other Utilities | 28 | 1.00 | 0.0 | 0.00000 | 0.00000 | 0.00000 |
| 36 | Trade | 29 | 1.00 | 2.2 | 0.00605 | 0.00664 | 0.00728 |
| 37 | Other | 30 | 1.00 | 0.0 | 0.00000 | 0.00000 | 0.00000 |

TABLE 3.4

DATA BASE FILE
SAMPLE AGRICULTURAL
WATER USE COEFFICIENT

| Livestock | Name | Intake l/day/head | Consumption % |
|---|---|---|---|
| 1 | beef cattle | 20.4 | 90 |
| 2 | dairy cattle | 54 | 70 |
| 3 | horses | 68 | 70 |
| 4 | pigs | 6 | 70 |
| 5 | sheep | 3.5 | 95 |
| 6 | poultry | .3 | 95 |

| Crop | Name | Intake m3/ha | Consumption % | Seasonal Distribution (% of intake) Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | grains | 5300 | 80 | 0 | 0 | 0 | 0 | 10 | 35 | 35 | 20 | 0 | 0 | 0 | 0 |
| 2 | forages | 7400 | 80 | 0 | 0 | 0 | 0 | 10 | 25 | 25 | 20 | 10 | 10 | 0 | 0 |
| 3 | sugar beets | 5100 | 80 | 0 | 0 | 0 | 0 | 10 | 30 | 30 | 20 | 10 | 0 | 0 | 0 |
| 4 | oilseeds | 4000 | 80 | 0 | 0 | 0 | 0 | 10 | 35 | 35 | 20 | 0 | 0 | 0 | 0 |
| 5 | specialty | 4700 | 80 | 0 | 0 | 0 | 0 | 10 | 35 | 35 | 20 | 0 | 0 | 0 | 0 |

TABLE 3.5

DATA BASE FILE
SAMPLE MUNICIPAL
WATER USE COEFFICIENT

| Usage Name | | Province | Intake l/day/capita | Consumption % | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Seasonal Distribution Factor | | | | | | | | | | | |
| Urban | | | | | | | | | | | | | | | | |
| 1 | residential | B. C. | 316 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| | | Alberta | 273 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| | | Saskatchewan | 203 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| | | Manitoba | 198 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| 2 | commercial | B. C. | 155 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| | | Alberta | 134 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| | | Saskatchewan | 100 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| | | Manitoba | 97 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| 3 | public | B. C. | 104 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| | | Alberta | 89 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| | | Saskatchewan | 66 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| | | Manitoba | 65 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| Rural | | | | | | | | | | | | | | | | |
| 1 | general | B. C. | 182 | 70 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| | | Alberta | 137 | 70 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| | | Saskatchewan | 137 | 70 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| | | Manitoba | 137 | 70 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |

1971, 1972 and 1976 based on the real growth of each industrial sector. Consideration has also been given to technological changes in the industry and the general increase in recirculation processes over once-through processes. Details of the derivation of the water use coefficients are presented in Appendix B.

Forecasts of growth in the industrial sectors are made by economic region using 1981 dollars as a basis. Basic input to the model therefore must include the proportion of the industrial sector total output from the economic region which is contributed by each subbasin. To establish this percentage it would be most appropriate to obtain the value of shipment data for each industrial sector by subbasin. These data are usually kept confidential by Statscan since there are often only a small number of businesses within each industrial sector in the subbasin. It is therefore necessary to relate industrial development to another measurable variable. The most reliable and readily available variable is labor force information which has been used in the test case to establish industrial sector percentages in each subbasin.

In some cases, the dollar output of a sector may not be the most accurate or appropriate indicator of water use. This is particularly true of the energy production sector where the installed capacity or annual generation data by generation type would be more accurate. This refinement has not been included for existing plants in the current model, but will be considered when the model is expanded in the future. When examining growth of the energy production sector, it is possible, of course, to input specific water use information. Water use rates related to energy developments are presented in Appendix C.

Water use within an industrial sector is extremely variable for a number of reasons, for example:

- Specific business types within a given industrial sector have widely varying water requirements. In the "Food and Beverages" sector for example, bottling and canning businesses will require substantially greater amounts of water than dry cereal production.

- Future economic conditions, currently uncertain, and political pressures for pollution abatement will affect water use within a given sector. As an example, pollution requirements of the future may dictate the need for wet cooling towers which have a higher consumptive use than once-through cooling.

- Development of new energy technologies which are water intensive such as coal and oil shale conversion would increase water requirements for the energy sector.

In light of this uncertainty in the projection of water use coefficients, it may well be better to adopt a range of potential water use coefficients as opposed to a "best guess." Water constraints on energy development, A Framework for Analyses (Reference 11) argues strongly for this.

> More precise estimates would certainly make the energy planning process easier, and thus there is some justification for making a best guess as to a particular value of water use and working with that guess. At the present time, however, advantages of being able to present precise numbers are far outweighed by the loss of information that occurs when the full range of uncertainty is obscured.

If the use of a range of water use coefficients is adopted, a second question then arises. The range of variability is inversely related to the size of the area under consideration. Water use within a given industrial sector can be extremely variable when viewed at the subbasin level due to the variation of business within a sector. This variability tends to be averaged out when considering large basins or provinces.

In Appendix B, both a best guess and a range of water use are presented for each industrial sector. The range presented is for a large basin or province and therefore does not account for the large variability which may be encountered at the subbasin level. When running the model, the user has the option of selecting the low, median or high water use coefficient.

(b) Agricultural Water Use

The model requires gross intake data to be supplied by the user in units of cubic metres per hectare per year for each crop type and litres per head for each livestock type. Consumption must be expressed as a percentage of this gross intake figure.

As noted previously, irrigation water requirements during a given month will vary substantially from area to area and from one year to the next as a function of precipitation, evapotranspiration and irrigation method. The water use rates which are included in the base data files are therefore default values only. The user should preferably provide subbasin-specific coefficients in the gauge basin file (Section 3.1.2) which will override the values given in the data base file.

The intake and consumptive data for livestock are generally constant from region to region and therefore national averaged data may be used with confidence.

(c) Municipal Water Use

Municipal water use is input to the data base file by province and has been divided into urban and rural categories. In each category the demand is expressed in litres per capita per day. The total water use is further subdivided by percentages into residential, commercial and public use, thereby permitting different growth rates to be applied to each.

A provision has been made to vary the water use monthly. This will allow the user to simulate a higher monthly requirement if, for example, lawn watering during the summer period causes the average demand to be exceeded.

The provincial domestic water withdrawal coefficients which are given in Table 3.6 are intended for use as default values when subbasin-specific data are not available. In all cases subbasin-specific data should be used if available. The data were obtained from Canada Water Year Books for 1975 and 1976 (Environment Canada, 1975, 1976). These data were originally derived from sample surveys which were carried out in 1972 for each of the major river basins in Canada. In the survey results, industrial water uses were separated from domestic uses where they could be clearly identified. In some cases a separation was not possible and the statistics in Table 3.6 therefore contain an indeterminate amount of water which is supplied to industry. This water will be of minor significance in most cases.

TABLE 3.6

MUNICIPAL WATER USE COEFFICIENTS

| | Per Capita Intake (L/d) Municipalities (>1,000 people) | Rural (<1,000 people) |
|---|---|---|
| Newfoundland | 593 | 182 |
| Prince Edward Island | 365 | 160 |
| Nova Scotia | 438 | 160 |
| New Brunswick | 593 | 160 |
| Quebec | 620 | 160 |
| Ontario | 502 | 160 |
| Manitoba | 360 | 137 |
| Saskatchewan | 369 | 137 |
| Alberta | 497 | 137 |
| British Columbia | 575 | 182 |
| North West Territories | 378 | 160 |
| Yukon Territory | 1 254* | 182 |
| Canada | 529 | 160 |

Municipal breakdown: Residential 55 percent
Commercial 27 percent
Public 18 percent

Consumption: 20 percent of intake for municipalities
70 percent of intake for rural

*Due to continuous flow in utilities to prevent freezing, consumption would not be 20 percent of withdrawals.

Municipal water withdrawal has been divided into three categories: residential, commercial and public. The approximate breakdown of withdrawals by user group is also shown in Table 3.6. Residential uses are solely household uses such as bathing, laundry, toilet, drinking and cooking. Commercial uses include small industrial establishments and comprise such uses as hotels, restaurants, service stations, car washes, etc. Public uses include street cleaning, watering of public parks and gardens, fountains, public swimming pools and fire-fighting.

Water consumption in a municipality refers to water which is withdrawn from the public supply system and is not returned directly to the public sewerage system. Consumption includes losses from evaporation and leakage in the distribution system. No detailed survey of consumptive use has been undertaken for the whole of Canada, however, data from the United States indicate that consumption is typically 20 percent of withdrawals for municipal uses. This value is an average and is subject to considerable variability due to such factors as lawn and garden use and losses from distribution systems. Water consumption in rural areas is a much larger percentage of withdrawals and is estimated in the United States to be approximately 70 percent of withdrawals.

The Canadian average municipal consumptive use factor is 58 L/d while the Canadian average rural consumptive use factor is 112 L/d. The difference in these consumptive rates is likely due to two factors: sewage handling and alternative use. Rural sewerage systems are septic systems with relatively shallow weeping tiles which feed the surface vegetation and, consequently, have high evapotranspiration losses. Alternatively, municipal sanitary sewerage systems are designed to be sealed and to ultimately (after treatment) discharge their effluent directly to water courses. Rural consumption use factors also include some agricultural uses which are not included in the municipal factors such as stock watering and washing.

It should be recognized that there is a relationship between water withdrawal coefficients and water availability. Generally in water deficient areas, withdrawal coefficients are lower. In many cases, this arises due to price structures and compulsory and voluntary conservation measures (limited lawn watering and car washing). Consequently, in any planning study, it should be recognized that municipal and rural domestic use coefficients can be reduced significantly if future demands require it.

### 3.1.2 - Gauge Data File

The "gauge" data file includes all data which are specific to one subbasin. Sample output from the file, which may be used in reference to the following discussion, is presented in Table 3.7. The file includes data already provided in the data base file, thereby permitting the user to override any basic data with subbasin-specific information if so desired. These data include the following.

(a) Agricultural water use, both by livestock and by irrigated crops.

As noted previously, it is important to obtain irrigation water use rates, both for intake and consumption,

TABLE 3.7

GAUGE DATA FILE
SAMPLE FILE OUTPUT

Gauge I.D.: 05ad007

Name: Lethbridge

Province: Alberta

Economic Region: Prairies

| Population | Usage | Intake l/day/capita | Consumption % | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Seasonal Distribution Factor | | | | | | | | | | | |
| Urban | | | | | | | | | | | | | | | |
| 76424 | residential | 273 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| | commercial | 134 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| | public | 89 | 20 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |
| Rural | | | | | | | | | | | | | | | |
| 28723 | general | 137 | 70 | .7 | .7 | .7 | 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1 | .7 | .7 |

| Livestock | 1,000's | Intake l/day/head | Consumption % |
|---|---|---|---|
| beef cattle | 336 | 20.4 | 90 |
| dairy cattle | 14 | 54 | 70 |
| horses | 7 | 68 | 70 |
| pigs | 86 | 6 | 70 |
| sheep | 52 | 3.5 | 95 |
| poultry | 839 | .3 | 95 |

Total Potential Crop Area: 1376000 ha

| Crop | Irrigated Area ha | Annual Intake m3/ha | Consumption % | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Seasonal Distribution (%) | | | | | | | | | | | |
| grains | 17234 | 4990 | 80 | 0 | 0 | 0 | 0 | 10 | 35 | 35 | 20 | 0 | 0 | 0 | 0 |
| forages | 26787 | 6940 | 80 | 0 | 0 | 0 | 0 | 10 | 25 | 25 | 20 | 10 | 10 | 0 | 0 |
| sugar beets | 1970 | 4790 | 80 | 0 | 0 | 0 | 0 | 10 | 30 | 30 | 20 | 10 | 0 | 0 | 0 |
| oilseeds | 1970 | 3760 | 80 | 0 | 0 | 0 | 0 | 10 | 35 | 35 | 20 | 0 | 0 | 0 | 0 |
| specialty | 1280 | 4450 | 80 | 0 | 0 | 0 | 0 | 10 | 35 | 35 | 20 | 0 | 0 | 0 | 0 |

Table 3.7
Gauge Data File
Sample File Output - 2

| Industry | Percentage of Region % | 3 Intake Coefficients MCM/$M/year | | | Recirc. Factor | Consumption % |
|---|---|---|---|---|---|---|
| Agriculture | 2.33 | 0.00000 | 0.00000 | 0.00000 | 1.00 | 0.0 |
| Forestry, etc. | 2.16 | 0.71500 | 0.79300 | 0.87100 | 2.59 | 75.0 |
| Metal Mines | 0.00 | 0.06900 | 0.21603 | 0.08379 | 3.66 | 75.9 |
| Fuels, Oil & Gas | 1.62 | 0.00411 | 0.01305 | 0.00512 | 2.62 | 75.9 |
| Fuels, Coal | 27.69 | 0.00505 | 0.01623 | 0.00674 | 2.64 | 75.9 |
| Non-Metal Mines | 0.23 | 0.08746 | 0.27864 | 0.11244 | 2.24 | 75.9 |
| Food & Beverages | 4.71 | 0.01344 | 0.03893 | 0.01648 | 1.42 | 7.1 |
| Tobacco | 0.00 | 0.00093 | 0.00109 | 0.00126 | 6.36 | 24.2 |
| Rubber | 0.00 | 0.13065 | 0.01432 | 0.15750 | 1.31 | 0.8 |
| Plastics | 3.85 | 0.19507 | 0.02120 | 0.23238 | 1.31 | 0.7 |
| Leather | 0.00 | 0.00373 | 0.00397 | 0.00421 | 1.10 | 6.9 |
| Textiles | 0.63 | 0.01226 | 0.01437 | 0.01606 | 1.71 | 5.3 |
| Wood | 4.32 | 0.04052 | 0.04468 | 0.04936 | 1.48 | 2.6 |
| Furniture | 1.08 | 0.00065 | 0.00072 | 0.00078 | 1.40 | 28.6 |
| Paper, Mills | 0.31 | 0.25452 | 0.28385 | 0.31245 | 3.13 | 3.7 |
| Paper, Finishing | 0.00 | 0.10169 | 0.11035 | 0.11900 | 3.10 | 3.6 |
| Printing | 2.17 | 0.00087 | 0.00097 | 0.00109 | 12.81 | 2.9 |
| Iron, Mills | 0.00 | 0.10739 | 0.00156 | 0.13236 | 2.50 | 25.0 |
| Iron, Foundries | 0.98 | 0.09928 | 0.00143 | 0.12018 | 2.50 | 25.0 |
| Other, Smelting | 0.00 | 0.18789 | 0.00273 | 0.23156 | 1.62 | 25.0 |
| Other, Extruding | 0.00 | 0.15508 | 0.00222 | 0.18998 | 1.63 | 25.0 |
| Metal Fabricating | 0.92 | 0.00355 | 0.00756 | 0.00452 | 2.22 | 3.8 |
| Machinery | 2.37 | 0.00165 | 0.00183 | 0.00200 | 1.78 | 61.3 |
| Trans. Equipment | 8.72 | 0.01726 | 0.01899 | 0.02040 | 1.50 | 0.4 |
| Electric Products | 6.90 | 0.00588 | 0.00625 | 0.00671 | 2.72 | 2.3 |
| Non-Metal Mineral | 1.93 | 0.03047 | 0.04560 | 0.03916 | 1.92 | 13.5 |
| Petrol Refineries | 0.24 | 0.04620 | 0.00510 | 0.05654 | 2.14 | 5.1 |
| Petroleum & Coal | 0.00 | 0.81177 | 0.08984 | 0.98134 | 2.13 | 5.1 |
| Chemicals, Indust | 0.28 | 0.12063 | 0.13372 | 0.14544 | 2.20 | 6.3 |
| Chemicals, Other | 4.32 | 0.19853 | 0.22153 | 0.24582 | 2.20 | 6.3 |
| Misc. Manufacture | 1.32 | 0.00380 | 0.00424 | 0.00460 | 2.10 | 11.0 |
| Construction | 2.57 | 0.00000 | 0.00000 | 0.00000 | 1.00 | 0.0 |
| Transportation | 1.97 | 0.00000 | 0.00000 | 0.00000 | 1.00 | 0.0 |
| Electric Power | 1.52 | 1.43936 | 1.59819 | 1.73717 | 1.00 | 1.1 |
| Other Utilities | 3.61 | 0.00000 | 0.00000 | 0.00000 | 1.00 | 0.0 |
| Trade | 2.55 | 0.00605 | 0.00664 | 0.00728 | 1.00 | 2.2 |
| Other | 2.33 | 0.00000 | 0.00000 | 0.00000 | 1.00 | 0.0 |

No. Other Supplies: 0

No. of Developments: 0

No. of Minimum Flows: 1

| | Monthly Flow (cu.m./sec.) Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .) All Purposes | 12 | 12 | 12 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 12 | 12 | ( 8.5 cms avg |

otal) ( 268.056 MCM

which are specific to a basin or subbasin. These data are often difficult to obtain by crop but may well be available as an average irrigation requirement. In this case, the average figure should be used for all crops in the subbasin.

(b) Industrial water use coefficients for each industrial sector.

These have been fully discussed in Section 3.1.1(a). It may be possible to derive water use coefficients which are specific to a region or subbasin if water use by industrial sector has been studied. This was the case for the South Saskatchewan basin where the Prairie Provinces Water Demand Study had reported industrial water use by industrial sector.

(c) Municipal water use in both urban and rural categories.

Sources of subbasin-specific information should be sought. Data may be provided in published reports or from municipalities in the subbasin.

The user must provide the following additional data, related directly to each subbasin.

(d) Urban and rural population.

These data are available from Statscan.

(e) Number of animals and irrigated area.

Statscan can provide data on the number of head of each livestock type and the total irrigated area by subbasin. It can also provide total area of each crop type by subbasin but cannot currently produce data on the irrigated area for each crop type. The user must make some assumption concerning the proportion of each crop which is irrigated.

(f) Economic output by industrial sector expressed as a percentage of the total output of the economic region.

(g) Volume of other supplies either into or out of the sub-basin.

A number of supplies or withdrawals from the subbasin can be modeled and this input is therefore used to simulate diversions into or out of the subbasin, or groundwater supply directly into the subbasin. Each supply or withdrawal is assigned a rate in millions of cubic metres per month for each month of the year.

(h) Water use data related to specific developments.

It is expected that most specific developments investigated will relate to the energy sector. Appendix C has been prepared as a general guide to the range of water use rates of specific types of energy-related projects.

(i) Minimum monthly outflows from the subbasin are also defined in the gauge basin data. These are designed to reflect minimum flow constraints for water quality or recreation. During execution, the model checks whether or not the flow constraint is violated and compiles statistics on the number of violations during the historic sequence being studied.

### 3.1.3 - Forecast Data

The forecast file will contain data for a variety of forecast scenarios provided by the user. Generally, these scenarios would be developed from outside agencies such as the Economic Council of Canada or the University of Toronto, however, it is possible for the user to generate his own forecast.

The calculation of municipal water use is based on per capita consumption and, therefore, a population forecast is required. Statscan produces four scenarios for population growth, depending on expected fertility rates and migration. A sample of the four scenarios is presented in Tables 3.8(a) to 3.8(d), with population growth in urban and rural areas expressed as additional people per thousand per year.

The industrial growth is forecasted for each basic industrial sector by economic region. Forecasts are presented in Table 3.9(a) from the Economic Council of Canada and in Tables 3.9(b) and 3.9(c) from the University of Toronto national forecasts. Growth is expressed as annual percentage real growth in 1981 constant dollars.

Agricultural forecasts are divided into irrigation and live-stock categories. The model requires the user to prepare forecasts of livestock increases expressed in percent per year change. It is possible to input any number of scenarios of growth, as illustrated in Table 3.10(a). Similarly, the user must prepare a forecast of irrigated area development, also expressed in annual percent change by crop [Table 3.10(b)]. In this case, during run execution, the model will check that the total area of a subbasin available for irrigation development is not exceeded.

TABLE 3.8(a)

FORECAST DATA FILE
SAMPLE FILE OUTPUT - POPULATION

No. of Years: 20 ( 1982 - 2001 )

POPULATION

No. of Scenarios: 4

| Scenario 1 * | Province | | Annual Change (number per 1,000) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
| | | | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
| Stats Canada 1 | B. C. | urban | 22.3 | 22.1 | 21.9 | 21.6 | 21.2 | 20.8 | 20.3 | 19.7 | 19.1 | 18.5 |
| | | | 17.8 | 17.1 | 16.4 | 15.8 | 15.2 | 14.7 | 14.2 | 13.8 | 13.4 | 13.1 |
| | | rural | 22.3 | 22.1 | 21.9 | 21.6 | 21.2 | 20.8 | 20.3 | 19.7 | 19.1 | 18.5 |
| | | | 17.8 | 17.1 | 16.4 | 15.8 | 15.2 | 14.7 | 14.2 | 13.8 | 13.4 | 13.1 |
| | Alberta | urban | 19.4 | 19.2 | 18.7 | 18.2 | 17.8 | 17.2 | 16.7 | 16.1 | 15.6 | 14.9 |
| | | | 14.3 | 13.6 | 13.0 | 12.5 | 12.0 | 11.5 | 11.2 | 10.8 | 10.5 | 10.3 |
| | | rural | 19.4 | 19.2 | 18.7 | 18.2 | 17.8 | 17.2 | 16.7 | 16.1 | 15.6 | 14.9 |
| | | | 14.3 | 13.6 | 13.0 | 12.5 | 12.0 | 11.5 | 11.2 | 10.8 | 10.5 | 10.3 |
| | Saskatchewan | urban | -0.6 | -0.2 | 0.2 | 0.5 | 0.7 | 0.9 | 0.9 | 0.9 | 0.9 | 0.8 |
| | | | 0.7 | 0.5 | 0.4 | 0.2 | 0.1 | 0.0 | 0.0 | -0.1 | 0.0 | 0.1 |
| | | rural | -0.6 | -0.2 | 0.2 | 0.5 | 0.7 | 0.9 | 0.9 | 0.9 | 0.9 | 0.8 |
| | | | 0.7 | 0.5 | 0.4 | 0.2 | 0.1 | 0.0 | 0.0 | -0.1 | 0.0 | 0.1 |
| | Manitoba | urban | 6.0 | 6.3 | 6.4 | 6.5 | 6.6 | 6.6 | 6.5 | 6.4 | 6.2 | 6.0 |
| | | | 5.6 | 5.4 | 5.1 | 4.8 | 4.6 | 4.4 | 4.3 | 4.2 | 4.1 | 4.1 |
| | | rural | 6.0 | 6.3 | 6.4 | 6.5 | 6.6 | 6.6 | 6.5 | 6.4 | 6.2 | 6.0 |
| | | | 5.6 | 5.4 | 5.1 | 4.8 | 4.6 | 4.4 | 4.3 | 4.2 | 4.1 | 4.1 |

*- slight increase in fertility rates
- net international migration = 100 000/yr
- historical pattern of interprovincial migration

TABLE 3.8(b)

FORECAST DATA FILE
SAMPLE FILE OUTPUT - POPULATION

| Scenario 2 *. | Province | | Annual Change (number per 1,000) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1982<br>1992 | 1983<br>1993 | 1984<br>1994 | 1985<br>1995 | 1986<br>1996 | 1987<br>1997 | 1988<br>1998 | 1989<br>1999 | 1990<br>2000 | 1991<br>2001 |
| Stats Canada 2 | B. C. | urban | 17.4 | 18.0 | 18.7 | 19.3 | 19.8 | 20.2 | 19.8 | 19.3 | 18.8 | 18.2 |
| | | | 17.6 | 16.9 | 16.3 | 15.7 | 15.1 | 14.6 | 14.2 | 13.8 | 13.4 | 13.1 |
| | | rural | 17.4 | 18.0 | 18.7 | 19.3 | 19.8 | 20.2 | 19.8 | 19.3 | 18.8 | 18.2 |
| | | | 17.6 | 16.9 | 16.3 | 15.7 | 15.1 | 14.6 | 14.2 | 13.8 | 13.4 | 13.1 |
| | Alberta | urban | 32.0 | 31.7 | 31.3 | 30.8 | 30.3 | 29.7 | 28.6 | 27.5 | 26.4 | 25.2 |
| | | | 24.1 | 23.0 | 22.0 | 21.0 | 20.1 | 19.3 | 18.6 | 17.9 | 17.4 | 16.9 |
| | | rural | 32.0 | 31.7 | 31.3 | 30.8 | 30.3 | 29.7 | 28.6 | 27.5 | 26.4 | 25.2 |
| | | | 24.1 | 23.0 | 22.0 | 21.0 | 20.1 | 19.3 | 18.6 | 17.9 | 17.4 | 16.9 |
| | Saskatchewan | urban | 11.6 | 10.9 | 10.2 | 9.4 | 8.6 | 7.6 | 7.5 | 7.4 | 7.2 | 6.9 |
| | | | 6.6 | 6.3 | 6.0 | 5.7 | 5.4 | 5.1 | 5.0 | 4.8 | 4.8 | 4.7 |
| | | rural | 11.6 | 10.9 | 10.2 | 9.4 | 8.6 | 7.6 | 7.5 | 7.4 | 7.2 | 6.9 |
| | | | 6.6 | 6.3 | 6.0 | 5.7 | 5.4 | 5.1 | 5.0 | 4.8 | 4.8 | 4.7 |
| | Manitoba | urban | 8.3 | 8.2 | 8.1 | 8.1 | 8.0 | 7.7 | 7.6 | 7.5 | 7.3 | 7.1 |
| | | | 6.8 | 6.5 | 6.2 | 5.9 | 5.7 | 5.5 | 5.3 | 5.2 | 5.2 | 5.2 |
| | | rural | 8.3 | 8.2 | 8.1 | 8.1 | 8.0 | 7.7 | 7.6 | 7.5 | 7.3 | 7.1 |
| | | | 6.8 | 6.5 | 6.2 | 5.9 | 5.7 | 5.5 | 5.3 | 5.2 | 5.2 | 5.2 |

*- same fertility rate as Scenario 1
- net international migration = 75 000/yr
- continued shift in migration away from Ontario to Alberta and B.C. for next 10 years

TABLE 3.8(c)

FORECAST DATA FILE
SAMPLE FILE OUTPUT - POPULATION

| Scenario 3 * | Province | | Annual Change (number per 1,000) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1982<br>1992 | 1983<br>1993 | 1984<br>1994 | 1985<br>1995 | 1986<br>1996 | 1987<br>1997 | 1988<br>1998 | 1989<br>1999 | 1990<br>2000 | 1991<br>2001 |
| Stats Canada 3 | B. C. | urban | 16.3 | 16.1 | 15.9 | 15.6 | 15.3 | 14.8 | 14.3 | 13.8 | 13.3 | 12.8 |
| | | | 12.3 | 11.8 | 11.3 | 10.8 | 10.4 | 10.0 | 9.6 | 9.2 | 8.9 | 8.6 |
| | | rural | 16.3 | 16.1 | 15.9 | 15.6 | 15.3 | 14.8 | 14.3 | 13.8 | 13.3 | 12.8 |
| | | | 12.3 | 11.8 | 11.3 | 10.8 | 10.4 | 10.0 | 9.6 | 9.2 | 8.9 | 8.6 |
| | Alberta | urban | 22.0 | 21.4 | 20.8 | 20.1 | 19.5 | 18.8 | 18.1 | 17.4 | 16.6 | 15.8 |
| | | | 15.1 | 14.4 | 13.7 | 13.1 | 12.5 | 12.0 | 11.5 | 11.0 | 10.6 | 10.2 |
| | | rural | 22.0 | 21.4 | 20.8 | 20.1 | 19.5 | 18.8 | 18.1 | 17.4 | 16.6 | 15.8 |
| | | | 15.1 | 14.4 | 13.7 | 13.1 | 12.5 | 12.0 | 11.5 | 11.0 | 10.6 | 10.2 |
| | Saskatchewan | urban | 5.6 | 5.8 | 5.9 | 5.9 | 5.9 | 5.8 | 5.6 | 5.3 | 5.0 | 4.8 |
| | | | 4.5 | 4.2 | 3.9 | 3.6 | 3.3 | 3.0 | 2.8 | 2.6 | 2.4 | 2.4 |
| | | rural | 5.6 | 5.8 | 5.9 | 5.9 | 5.9 | 5.8 | 5.6 | 5.3 | 5.0 | 4.8 |
| | | | 4.5 | 4.2 | 3.9 | 3.6 | 3.3 | 3.0 | 2.8 | 2.6 | 2.4 | 2.4 |
| | Manitoba | urban | 5.5 | 5.6 | 5.7 | 5.7 | 5.7 | 5.6 | 5.4 | 5.2 | 4.9 | 4.6 |
| | | | 4.3 | 4.1 | 3.8 | 3.6 | 3.3 | 3.1 | 2.9 | 2.8 | 2.7 | 2.6 |
| | | rural | 5.5 | 5.6 | 5.7 | 5.7 | 5.7 | 5.6 | 5.4 | 5.2 | 4.9 | 4.6 |
| | | | 4.3 | 4.1 | 3.8 | 3.6 | 3.3 | 3.1 | 2.9 | 2.8 | 2.7 | 2.6 |

*- decreased fertility rate
- net international migration = 75 000/yr
- historical pattern of interprovincial migration

TABLE 3.8(d)

FORECAST DATA FILE
SAMPLE FILE OUTPUT - POPULATION

| Scenario 4 * | Province | | Annual | Change | (number per 1,000) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1982<br>1992 | 1983<br>1993 | 1984<br>1994 | 1985<br>1995 | 1986<br>1996 | 1987<br>1997 | 1988<br>1998 | 1989<br>1999 | 1990<br>2000 | 1991<br>2001 |
| Stats Canada 4 | B. C. | urban | 11.5 | 11.4 | 11.3 | 11.2 | 11.0 | 10.7 | 10.3 | 10.0 | 9.6 | 9.2 |
| | | | 8.8 | 8.4 | 8.0 | 7.6 | 7.3 | 7.0 | 6.7 | 6.4 | 6.2 | 6.0 |
| | | rural | 11.5 | 11.4 | 11.3 | 11.2 | 11.0 | 10.7 | 10.3 | 10.0 | 9.6 | 9.2 |
| | | | 8.8 | 8.4 | 8.0 | 7.6 | 7.3 | 7.0 | 6.7 | 6.4 | 6.2 | 6.0 |
| | Alberta | urban | 26.3 | 25.5 | 24.7 | 23.9 | 23.1 | 22.3 | 21.4 | 20.5 | 19.6 | 18.7 |
| | | | 17.8 | 17.0 | 16.2 | 15.5 | 14.8 | 14.1 | 13.5 | 12.9 | 12.4 | 12.0 |
| | | rural | 26.3 | 25.5 | 24.7 | 23.9 | 23.1 | 22.3 | 21.4 | 20.5 | 19.6 | 18.7 |
| | | | 17.8 | 17.0 | 16.2 | 15.5 | 14.8 | 14.1 | 13.5 | 12.9 | 12.4 | 12.0 |
| | Saskatchewan | urban | 13.4 | 13.5 | 13.4 | 13.2 | 12.9 | 12.7 | 12.3 | 11.8 | 11.3 | 10.8 |
| | | | 10.3 | 9.8 | 9.3 | 8.8 | 8.3 | 7.9 | 7.5 | 7.2 | 6.9 | 6.6 |
| | | rural | 13.4 | 13.5 | 13.4 | 13.2 | 12.9 | 12.7 | 12.3 | 11.8 | 11.3 | 10.8 |
| | | | 10.3 | 9.8 | 9.3 | 8.8 | 8.3 | 7.9 | 7.5 | 7.2 | 6.9 | 6.6 |
| | Manitoba | urban | 6.6 | 6.7 | 6.8 | 6.8 | 6.7 | 6.6 | 6.4 | 6.1 | 5.8 | 5.5 |
| | | | 5.2 | 4.9 | 4.6 | 4.3 | 4.0 | 3.7 | 3.5 | 3.3 | 3.2 | 3.1 |
| | | rural | 6.6 | 6.7 | 6.8 | 6.8 | 6.7 | 6.6 | 6.4 | 6.1 | 5.8 | 5.5 |
| | | | 5.2 | 4.9 | 4.6 | 4.3 | 4.0 | 3.7 | 3.5 | 3.3 | 3.2 | 3.1 |

* - same decrease in fertility as Scenario 3
- net international migration = 50 000/yr
- continued shift away from Ontario to Alberta and B.C. for entire period

TABLE 3.9(a)

FORECAST DATA FILE
SAMPLE OUTPUT - INDUSTRY

Scenario 1 Economic Council of Canada, 1981-1990 (without regional effects)

| Industry | Annual Percentage Change | | | | |
|---|---|---|---|---|---|
| | BC | Prairies | Ontario | Quebec | Maritime |
| Agriculture | -.68 | -.68 | -.68 | -.68 | -.68 |
| Forestry, etc. | 4.52 | 4.52 | 4.52 | 4.52 | 4.62 |
| Metal Mines | 4.17 | 4.17 | 4.17 | 4.17 | 4.71 |
| Fuels, Oil & Gas | 3.13 | 3.13 | 3.13 | 3.13 | 3.13 |
| Fuels, Coal | 7.93 | 7.93 | 7.93 | 7.93 | 7.93 |
| Non-Metal Mines | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 |
| Food & Beverages | 1.38 | 1.38 | 1.38 | 1.38 | 1.38 |
| Tobacco | .35 | .35 | .35 | .35 | .35 |
| Rubber | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 |
| Plastics | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 |
| Leather | 2.31 | 2.31 | 2.31 | 2.31 | 2.31 |
| Textiles | 2.46 | 2.46 | 2.46 | 2.46 | 2.46 |
| Wood | 3.29 | 3.29 | 3.29 | 3.29 | 3.29 |
| Furniture | 2.74 | 2.74 | 2.74 | 2.74 | 2.74 |
| Paper, Mills | 4.15 | 4.15 | 4.15 | 4.15 | 4.15 |
| Paper, Finishing | 4.15 | 4.15 | 4.15 | 4.15 | 4.15 |
| Printing | 3.44 | 3.44 | 3.44 | 3.44 | 3.44 |
| Iron, Mills | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| Iron, Foundries | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| Other, Smelting | 2.19 | 2.19 | 2.19 | 2.19 | 2.19 |
| Other, Extruding | 2.19 | 2.19 | 2.19 | 2.19 | 2.19 |
| Metal Fabricating | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 |
| Machinery | 3.48 | 3.48 | 3.48 | 3.48 | 3.48 |
| Trans. Equipment | 2.46 | 2.46 | 2.46 | 2.46 | 2.46 |
| Electric Products | 4.05 | 4.05 | 4.05 | 4.05 | 4.05 |
| Non-Metal Mineral | 3.65 | 3.65 | 3.65 | 3.65 | 3.65 |
| Petrol Refineries | 1.66 | 1.66 | 1.66 | 1.66 | 1.66 |
| Petroleum & Coal | 1.66 | 1.66 | 1.66 | 1.66 | 1.66 |
| Chemicals, Indust | 2.54 | 2.54 | 2.54 | 2.54 | 2.54 |
| Chemicals, Other | 2.54 | 2.54 | 2.54 | 2.54 | 2.54 |
| Misc. Manufacture | 3.34 | 3.34 | 3.34 | 3.34 | 3.34 |
| Construction | 2.76 | 2.76 | 2.76 | 2.76 | 2.76 |
| Transportation | 2.76 | 2.76 | 2.76 | 2.76 | 2.76 |
| Electric Power | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 |
| Other Utilities | 2.76 | 2.76 | 2.76 | 2.76 | 2.76 |
| Trade | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| Other | 2.76 | 2.76 | 2.76 | 2.76 | 2.76 |

TABLE 3.9(b)

FORECAST DATA FILE
SAMPLE OUTPUT - INDUSTRY

Scenario 2 U. of T.-National, 1981-95 (without regional effects)

| Industry | Annual Percentage Change | | | | |
|---|---|---|---|---|---|
| | BC | Prairies | Ontario | Quebec | Maritime |
| Agriculture | .67 | .67 | .67 | .67 | .67 |
| Forestry, etc. | 1.29 | 1.29 | 1.29 | 1.29 | 1.29 |
| Metal Mines | .05 | .05 | .05 | .05 | .05 |
| Fuels, Oil & Gas | 2.52 | 2.52 | 2.52 | 2.52 | 2.52 |
| Fuels, Coal | 2.52 | 2.52 | 2.52 | 2.52 | 2.52 |
| Non-Metal Mines | .05 | .05 | .05 | .05 | .05 |
| Food & Beverages | .78 | .78 | .78 | .78 | .78 |
| Tobacco | .78 | .78 | .78 | .78 | .78 |
| Rubber | .67 | .67 | .67 | .67 | .67 |
| Plastics | .67 | .67 | .67 | .67 | .67 |
| Leather | .82 | .82 | .82 | .82 | .82 |
| Textiles | .82 | .82 | .82 | .82 | .82 |
| Wood | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| Furniture | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| Paper, Mills | 1.63 | 1.63 | 1.63 | 1.63 | 1.63 |
| Paper, Finishing | 1.63 | 1.63 | 1.63 | 1.63 | 1.63 |
| Printing | 1.63 | 1.63 | 1.63 | 1.63 | 1.63 |
| Iron, Mills | .82 | .82 | .82 | .82 | .82 |
| Iron, Foundries | .82 | .82 | .82 | .82 | .82 |
| Other, Smelting | .82 | .82 | .82 | .82 | .82 |
| Other, Extruding | .82 | .82 | .82 | .82 | .82 |
| Metal Fabricating | .82 | .82 | .82 | .82 | .82 |
| Machinery | 1.11 | 1.11 | 1.11 | 1.11 | 1.11 |
| Trans. Equipment | 1.11 | 1.11 | 1.11 | 1.11 | 1.11 |
| Electric Products | -.39 | -.39 | -.39 | -.39 | -.39 |
| Non-Metal Mineral | 1.57 | 1.57 | 1.57 | 1.57 | 1.57 |
| Petrol Refineries | .67 | .67 | .67 | .67 | .67 |
| Petroleum & Coal | .67 | .67 | .67 | .67 | .67 |
| Chemicals, Indust | .67 | .67 | .67 | .67 | .67 |
| Chemicals, Other | .67 | .67 | .67 | .67 | .67 |
| Misc. Manufacture | -.83 | -.83 | -.83 | -.83 | -.83 |
| Construction | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Transportation | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Electric Power | 3.87 | 3.87 | 3.87 | 3.87 | 3.87 |
| Other Utilities | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Trade | 2.57 | 2.57 | 2.57 | 2.57 | 2.57 |
| Other | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |

TABLE 3.9(c)

FORECAST DATA FILE
SAMPLE OUTPUT - INDUSTRY

Scenario 3 U. of T.-B.C.& Alberta, 1981-95 (without regional effects)

| Industry | Annual Percentage Change | | | | |
|---|---|---|---|---|---|
| | BC | Prairies | Ontario | Quebec | Maritime |
| Agriculture | 1.58 | 1.32 | 0.67 | 0.67 | 0.67 |
| Forestry, etc. | 2.22 | 0.96 | 1.29 | 1.29 | 1.29 |
| Metal Mines | 1.44 | 0.00 | 0.05 | 0.05 | 0.05 |
| Fuels, Oil & Gas | 4.18 | 1.74 | 2.52 | 2.52 | 2.52 |
| Fuels, Coal | 4.18 | 1.74 | 2.52 | 2.52 | 2.52 |
| Non-Metal Mines | 1.44 | 2.40 | 0.05 | 0.05 | 0.05 |
| Food & Beverages | 1.18 | 1.46 | 0.78 | 0.78 | 0.78 |
| Tobacco | 0.00 | 0.00 | 0.78 | 0.78 | 0.78 |
| Rubber | 4.25 | 3.79 | 0.67 | 0.67 | 0.67 |
| Plastics | 4.25 | 3.79 | 0.67 | 0.67 | 0.67 |
| Leather | 2.30 | 0.99 | 0.82 | 0.82 | 0.82 |
| Textiles | 2.30 | 0.99 | 0.82 | 0.82 | 0.82 |
| Wood | 1.30 | 2.70 | 1.20 | 1.20 | 1.20 |
| Furniture | 1.30 | 2.70 | 1.20 | 1.20 | 1.20 |
| Paper, Mills | 3.30 | 4.60 | 1.63 | 1.63 | 1.63 |
| Paper, Finishing | 3.30 | 4.60 | 1.63 | 1.63 | 1.63 |
| Printing | 3.30 | 4.60 | 1.63 | 1.63 | 1.63 |
| Iron, Mills | 0.77 | 3.37 | 0.82 | 0.82 | 0.82 |
| Iron, Foundries | 0.77 | 3.37 | 0.82 | 0.82 | 0.82 |
| Other, Smelting | 0.77 | 3.37 | 0.82 | 0.82 | 0.82 |
| Other, Extruding | 0.77 | 3.37 | 0.82 | 0.82 | 0.82 |
| Metal Fabricating | 0.77 | 3.37 | 0.82 | 0.82 | 0.82 |
| Machinery | 2.95 | 4.08 | 1.11 | 1.11 | 1.11 |
| Trans. Equipment | 2.95 | 4.08 | 1.11 | 1.11 | 1.11 |
| Electric Products | -0.48 | 1.99 | -0.39 | -0.39 | -0.39 |
| Non-Metal Mineral | 2.82 | 4.04 | 1.57 | 1.57 | 1.57 |
| Petrol Refineries | 4.25 | 3.79 | 0.67 | 0.67 | 0.67 |
| Petroleum & Coal | 4.25 | 3.79 | 0.67 | 0.67 | 0.67 |
| Chemicals, Indust | 4.25 | 3.79 | 0.67 | 0.67 | 0.67 |
| Chemicals, Other | 4.25 | 3.79 | 0.67 | 0.67 | 0.67 |
| Misc. Manufacture | -0.53 | 1.31 | -0.83 | -0.83 | -0.83 |
| Construction | 3.35 | 3.41 | 2.50 | 2.50 | 2.50 |
| Transportation | 3.35 | 3.41 | 2.50 | 2.50 | 2.50 |
| Electric Power | 5.15 | 4.92 | 3.87 | 3.87 | 3.87 |
| Other Utilities | 3.35 | 3.41 | 2.50 | 2.50 | 2.50 |
| Trade | 3.25 | 3.58 | 2.57 | 2.57 | 2.57 |
| Other | 3.35 | 3.41 | 2.50 | 2.50 | 2.50 |

TABLE 3.10(a)

FORECAST DATA FILE
SAMPLE OUTPUT - LIVESTOCK

LIVESTOCK

No. of Scenarios: 3

| Scenario | Province | Annual Percentage Change | | | | | |
|---|---|---|---|---|---|---|---|
| | | beef cattle | dairy cattle | horses | pigs | sheep | poultry |
| 1 low | B. C. | 0.65 | -0.48 | 0.07 | -2.99 | -1.97 | 0.34 |
| | Alberta | 1.02 | -1.67 | -1.07 | -1.45 | -2.05 | -1.21 |
| | Saskatchewan | 0.91 | -1.71 | -0.78 | -0.98 | -2.41 | -1.63 |
| | Manitoba | 0.10 | -2.67 | -0.92 | 0.28 | -1.85 | -0.68 |
| 2 expected | B. C. | 1.55 | 0.32 | 1.20 | -2.27 | -0.50 | 1.15 |
| | Alberta | 1.92 | 0.00 | 0.08 | -0.40 | -0.83 | 0.60 |
| | Saskatchewan | 1.82 | -0.51 | -0.40 | 0.22 | -1.00 | -0.59 |
| | Manitoba | 1.06 | -0.57 | -0.21 | 1.72 | -0.78 | 0.00 |
| 3 high | B. C. | 2.44 | 0.83 | 2.13 | 1.59 | 0.89 | 1.68 |
| | Alberta | 2.84 | 1.56 | 0.49 | 1.45 | 1.10 | 0.33 |
| | Saskatchewan | 2.73 | 0.87 | 0.40 | 2.55 | 0.00 | 0.63 |
| | Manitoba | 2.56 | 2.08 | 0.53 | 3.23 | 0.21 | 0.97 |

TABLE 3.10(b)

FORECAST DATA FILE
SAMPLE OUTPUT - IRRIGATION

IRRIGATION
----------

No. of Scenarios: 3

| Scenario | Province | Annual Percentage Change | | | | |
|---|---|---|---|---|---|---|
| | | grains | forages | sugar beets | oilseeds | specialty |
| 1 expected | B. C. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Alberta | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| | Saskatchewan | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | Manitoba | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 high | B. C. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Alberta | 1.30 | 1.30 | 1.30 | 1.30 | 1.30 |
| | Saskatchewan | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 |
| | Manitoba | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 highest | B. C. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Alberta | 2.65 | 2.65 | 2.65 | 2.65 | 2.65 |
| | Saskatchewan | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| | Manitoba | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

INDUSTRIAL
----------

No. of Scenarios: 3

Statscan does not produce a forecast of growth in these areas, however, other agencies in the country may well do so. In executing the test case, low, expected, and high scenarios were developed from an extrapolation of historic data.

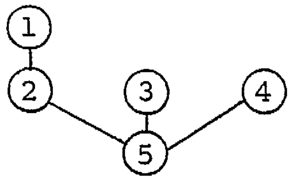
In considering the industrial economic growth scenarios, the user has the option of either cascading the increase in economic output through the regional and interregional input/output matrices or bypassing the cascading routine.

The cascading option will typically be selected when applying a user generated forecast. The impact of an increase in economic output for each industrial sector in an economic region on the output of that same industrial sector in another economic region is first determined using the interregional input/output matrices. Secondly, the impact of growth in one industrial sector on another industrial sector in the same economic region is determined using the intraregional input/output matrices. Further discussion of these matrices is provided in Section 3.1.7.

Other growth scenarios, such as those produced by the University of Toronto, have already considered the multiplier effect of growth in one region or industry on other regions or industries. For these scenarios, the cascading calculations should be bypassed.

### 3.1.4 - Basin Configuration File

The basic computation element of the model is the subbasin, as defined by a set of flow data at the subbasin outlet. The model arranges the subbasins in a hierarchical relationship according to user instructions in order to properly account for water available to downstream subbasins from subbasins farther upstream. The following figure shows a typical basin configuration containing five subbasins. It is numbered in ascending order from upstream to downstream which is a basic requirement of the model.




The purpose of the basin configuration file is to define the hierarchical relationship of the various subbasins. Typical output from the file is shown in Table 3.11.

3.1.5 - Gauge Hydrology File and Basin Hydrology File

Naturalized monthly flow data at the outlet to the subbasins are used as the measure of surface water availability. These records will, of course, reflect the runoff from the full drainage area upstream from the gauge and are labeled as the "gauge hydrology file" in the model. Sample output from this file is shown in Table 3.12. The subbasin hierarchical relationship, as defined in the basin configuration file, is used to apportion the total flows into inflows generated by each subbasin. The resulting file is labeled the "basin hydrology file" in the model and sample output from this file is presented in Table 3.13.

The historic flows, as recorded at the gauge points, include the effects of major withdrawals from the stream such as irrigation requirements. The records also include the effects of man-made regulation. To avoid double counting of water use requirements, the effects of withdrawals from the stream must be eliminated by adding these withdrawals to the records. For the Prairie provinces, this has been done by the Prairie Provinces Water Board and the data are available on computer tape.

TABLE 3.11

BASIN CONFIGURATION FILE
SAMPLE OUTPUT

Number of Nodes: 5

| Node No. | I.D. | No. of Upstream Nodes | Upstream Node Numbers | Downstream Node No. |
|---|---|---|---|---|
| 1 | 05CC002 | 0 | ( 0 0 0 ) | 2 |
| 2 | 05CE001 | 1 | ( 1 0 0 ) | 5 |
| 3 | 05CH007 | 0 | ( 0 0 0 ) | 5 |
| 4 | 05CE005 | 0 | ( 0 0 0 ) | 5 |
| 5 | 05CK004 | 3 | ( 2 3 4 ) | 0 |

TABLE 3.12

GAUGE HYDROLOGY FILE
SAMPLE OUTPUT

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 204 | 175 | 179 | 2420 | 2637 | 2639 | 1818 | 1311 | 697 | 556 | 307 | 170 |
| 1922 | 131 | 154 | 173 | 492 | 3014 | 2634 | 1795 | 2139 | 1073 | 634 | 342 | 121 |
| 1923 | 142 | 133 | 159 | 874 | 1547 | 12939 | 4884 | 4482 | 1952 | 1117 | 577 | 395 |
| 1924 | 306 | 366 | 601 | 1851 | 2930 | 3750 | 3016 | 3116 | 1297 | 839 | 486 | 322 |
| 1925 | 298 | 286 | 378 | 3768 | 1702 | 3417 | 1920 | 2945 | 2914 | 2823 | 1210 | 635 |
| 9999 | | | | | | | | | | | | |

TABLE 3.13

BASIN HYDROLOGY FILE
SAMPLE OUTPUT

Number of years: 5

| Gauge | Year | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 05CC002 | 1921 | 204 | 175 | 179 | 2420 | 2637 | 2639 | 1818 | 1311 | 697 | 556 | 307 | 170 |
| 05CE001 | 1921 | -25 | 6 | 77 | 942 | 183 | 64 | 155 | 218 | 267 | -46 | 5 | -10 |
| 05CH007 | 1921 | 0 | 2 | 22 | 266 | 0 | 0 | 0 | 0 | 9 | 0 | 1 | 0 |
| 05CE005 | 1921 | 0 | 2 | 21 | 255 | 205 | 305 | 268 | 258 | 244 | 43 | 1 | 0 |
| 05CK004 | 1921 | -37 | 6 | 72 | 886 | 721 | 1302 | 1468 | 1403 | 804 | 715 | 6 | -15 |
| 05CC002 | 1922 | 131 | 154 | 173 | 492 | 3014 | 2634 | 1795 | 2139 | 1073 | 634 | 342 | 121 |
| 05CE001 | 1922 | -29 | -48 | 20 | 489 | 244 | 305 | 374 | 377 | 431 | 62 | 4 | 6 |
| 05CH007 | 1922 | 0 | 0 | 6 | 138 | 6 | 0 | 22 | 26 | 48 | 4 | 1 | 2 |
| 05CE005 | 1922 | 0 | 0 | 5 | 132 | 229 | 335 | 317 | 311 | 308 | 51 | 1 | 2 |
| 05CK004 | 1922 | -43 | -71 | 20 | 460 | 996 | 2099 | 2207 | 1987 | 1160 | 1112 | 3 | 6 |
| 05CC002 | 1923 | 142 | 133 | 159 | 874 | 1547 | 12939 | 4884 | 4482 | 1952 | 1117 | 577 | 395 |
| 05CE001 | 1923 | -34 | -31 | -18 | 229 | 177 | -136 | 630 | 301 | 414 | 111 | 78 | -15 |
| 05CH007 | 1923 | 0 | 0 | 0 | 65 | 0 | 0 | 92 | 2 | 40 | 18 | 22 | 0 |
| 05CE005 | 1923 | 0 | 0 | 0 | 62 | 231 | 346 | 391 | 296 | 310 | 65 | 21 | 0 |
| 05CK004 | 1923 | -50 | -47 | -28 | 214 | 832 | 1276 | 2290 | 1780 | 1069 | 1084 | 74 | -23 |
| 05CC002 | 1924 | 306 | 366 | 601 | 1851 | 2930 | 3750 | 3016 | 3116 | 1297 | 839 | 486 | 322 |
| 05CE001 | 1924 | -72 | -69 | -146 | -286 | 259 | -116 | 304 | 310 | 374 | 124 | 69 | 12 |
| 05CH007 | 1924 | 0 | 0 | 0 | 0 | 19 | 0 | 14 | 18 | 41 | 23 | 19 | 3 |
| 05CE005 | 1924 | 0 | 0 | 0 | 0 | 211 | 287 | 268 | 263 | 267 | 63 | 19 | 3 |
| 05CK004 | 1924 | -107 | -102 | -217 | -427 | 1287 | 2089 | 2713 | 2446 | 1394 | 1453 | 65 | 12 |
| 05CC002 | 1925 | 298 | 286 | 378 | 3768 | 1702 | 3417 | 1920 | 2945 | 2914 | 2823 | 1210 | 635 |
| 05CE001 | 1925 | -54 | -54 | 22 | 1023 | 253 | 157 | 265 | 220 | 308 | 3 | 112 | 45 |
| 05CH007 | 1925 | 0 | 0 | 6 | 289 | 25 | 0 | 14 | 4 | 32 | 0 | 32 | 13 |
| 05CE005 | 1925 | 0 | 0 | 6 | 277 | 187 | 243 | 229 | 211 | 224 | 34 | 30 | 12 |
| 05CK004 | 1925 | -80 | -81 | 21 | 961 | 741 | 1310 | 1467 | 1287 | 781 | 689 | 105 | 42 |

The Water Use Forecasting Model, as it currently stands, requires that the effects of reservoir operation be included in the data. Where the records have been naturalized to remove the effects of man-made regulation, the effects should be put back into the data. An example of how this was done for the test case on the South Saskatchewan basin is discussed in Section 6.4.1. Reservoir simulation should be a feature considered for future development of the model.

### 3.1.6 - Gauge Forecast File

The model combines the gauge data, the basin configuration data and the demand forecast data files to create a gauge run file which contains similar data to the gauge data file except that data have been escalated to the forecast year. This file is created by the program and not by the user.

### 3.1.7 - Input/Output Matrix Files

Input/output matrices display the output interrelationships between sectors of the economy. These linkages are generally based on the value of production and/or services exchanged between the sectors. There are basically two types of matrices contained in the model: intraregional matrices express the linkages between sectors within an economic region of Canada; interregional matrices express the linkages between economic regions. If the user is applying an industrial forecast which has these effects built in, it is possible to bypass use of the matrices in the model. If, on the other hand, the forecast does not include the effects, then the option of applying the matrices should be selected. In this case, the model will route the forecast industrial growth first through the appropriate interregional matrices, followed by the intraregional matrix for the economic region of interest. The matrices are discussed individually below.

(a) Interregional Matrices

A sample interregional matrix for forestry is presented in Table 3.14. One of these has been prepared for each industrial sector based on interprovincial trade flows for 1974. The matrix shows the linkage between economic regions and international trade. The coefficients in the matrix show the output required from each region to meet a one dollar increase in final output from the region of interest. Using Table 3.14 as an example, a one dollar increase in forestry output in British Columbia would be contributed from the economic regions as follows.

| | | |
|---|---|---|
| BC | 0.9612 | (Row 1, Column 1) |
| Prairies | 0.0003 | (Row 2, Column 1) |
| Ontario | 0.0001 | (Row 3, Column 1) |
| Quebec | 0.0000 | (Row 4, Column 1) |
| Atlantic | 0.0000 | (Row 5, Column 1) |
| International | 0.0384 | (Row 6, Column 1) |

It is, of course, necessary that the columns of each matrix sum to 1.0.

(b) Intraregional Input/Output Matrices

For the purpose of industrial water use forecasting, inverse input/output matrices have been developed by Statscan (based on the 1974 national input/ output data) for the 30 major industrial sectors and for the 5 economic regions. The matrix developed for the Prairie provinces is presented in Table 3.15. The coefficients in the matrix show the output which would result from each sector for a one-unit increase in final output within another industrial sector. These coefficients

TABLE 3.14

SAMPLE INTERREGIONAL MATRIX

Sector 2 - Forestry

| | BC | Prairies | Ontario | Quebec | Atlantic | International |
|---|---|---|---|---|---|---|
| B.C. | .9612 | .0350 | .0027 | .0007 | .0001 | .4610 |
| Prairies | .0003 | .8846 | .0004 | .0000 | .0000 | .0889 |
| Ontario | .0001 | .0026 | .8640 | .0010 | .0000 | .1235 |
| Quebec | .0000 | .0002 | .0045 | .8882 | .0070 | .0853 |
| Atlantic | .0000 | .0000 | .0002 | .0002 | .9735 | .2412 |
| International | .0384 | .0775 | .1283 | .1099 | .0194 | .0000 |

correspond to the multipliers that result due to the interconnection of sectors within a region's economy. Using Table 3.15 as an example, a dollar increase in output of the forestry sector (Sector 2) would cause a 0.02137 dollar increase in the agricultural sector (Row 2, Column 1), a 0.23194 dollar compounded increase in the forestry sector (Row 2, Column 2), a 0.00128 dollar increase in the metal mines sector, etc.

## 3.2 - Run Analysis

The computational module of the program is very straightforward. The model examines each subbasin in turn, working from upstream to downstream. Within each subbasin, the water use is determined by calculating both the total intake and the total consumption for each month of the simulated period. The water availability is determined as the summation of flows from an upstream subbasin, local inflows plus diverted amounts. Comparison of water use and water availability is made monthly and the results are tabulated. The most critical months are identified and a frequency histogram is produced for both total intake and total consumption. Typical output from the model is illustrated in Table 3.16.

## 3.3 - Interpretation of Results

There are only a limited number of specific guidelines which can be given now concerning the interpretation of results. These are listed below. Other guidelines will undoubtedly be developed as the model is used.

(a) If the ratio of gross intake to supply exceeds 1.0 in a month.

TABLE 3.15

SAMPLE INTRAREGIONAL INPUT/OUTPUT MATRICES
PRAIRIES ECONOMIC REGION

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .04174 | .00191 | .00090 | .00174 | .00122 | .14697 | .00000 | .00087 | .00109 | .00406 | .00250 | .00117 | .00230 | .00113 | .00070 |
| 2 | .02137 | .23194 | .00128 | .00233 | .00276 | .07822 | .00000 | .00316 | .01000 | .00214 | .48676 | .04003 | .18288 | .03201 | .00129 |
| 3 | .00012 | .00043 | .00135 | .00021 | .00032 | .00016 | .00000 | .00013 | .00013 | .00006 | .00025 | .00028 | .00025 | .00027 | .10855 |
| 4 | .00591 | .00807 | .00356 | .00390 | .00736 | .00332 | .00000 | .00211 | .00078 | .00124 | .00522 | .00140 | .01046 | .00264 | .00723 |
| 5 | .00138 | .00139 | .02667 | .01748 | .04679 | .00078 | .00000 | .00038 | .00024 | .00015 | .00085 | .00029 | .00102 | .00036 | .00376 |
| 6 | .18572 | .00548 | .00243 | .00515 | .00325 | .09848 | .00000 | .00236 | .00266 | .00267 | .00460 | .00195 | .00359 | .00249 | .00168 |
| 7 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 8 | .00036 | .00038 | .00018 | [illegible] | .00025 | .00114 | .00000 | .01016 | .00071 | .00175 | .00042 | .00891 | .00041 | .00026 | .00014 |
| 9 | .00000 | .00002 | .00001 | .00001 | .00001 | .00001 | .00000 | .00003 | .00386 | .00053 | .00001 | .00020 | .00002 | .00013 | .00000 |
| 10 | .00046 | .00108 | .00019 | .00019 | .00030 | .00023 | .00000 | .00075 | .00735 | .04464 | .00054 | .00932 | .00029 | .00014 | .00007 |
| 11 | .00257 | .00303 | .00146 | .00290 | .00280 | .00453 | .00000 | .00354 | .01907 | .00233 | .08129 | .08318 | .14437 | .02537 | .00182 |
| 12 | .00003 | .00009 | .00003 | .00005 | .00004 | .00004 | .00000 | .00003 | .00004 | .00002 | .00088 | .00637 | .00022 | .00006 | .00002 |
| 13 | .00510 | .00294 | .00184 | .00298 | .00756 | .02263 | .00000 | .01102 | .00857 | .00671 | .00480 | .01205 | .04051 | .17901 | .00209 |
| 14 | .00214 | .00518 | .00268 | .00572 | .00367 | .00473 | .00000 | .00223 | .00302 | .00192 | .00500 | .00244 | .00370 | .04823 | .00184 |
| 15 | .00034 | .00049 | .00320 | .00171 | .00145 | .00057 | .00000 | .00018 | .00069 | .00008 | .00032 | .00095 | .00032 | .00018 | .00472 |
| 16 | .00060 | .00113 | .00853 | .00119 | .00165 | .00075 | .00000 | .00088 | .00068 | .00027 | .00089 | .00224 | .00167 | .00215 | .03702 |
| 17 | .00897 | .00633 | .00352 | .00384 | .00217 | .01769 | .00000 | .00434 | .00849 | .00138 | .00574 | .02693 | .00740 | .00276 | .00488 |
| 18 | .00082 | .00374 | .00446 | .00507 | .00425 | .00104 | .00000 | .00079 | .01477 | .00051 | .00223 | .00108 | .00138 | .00187 | .00473 |
| 19 | .00035 | .00744 | .00026 | .00048 | .00041 | .00071 | .00000 | .00066 | .00032 | .00018 | .00322 | .00057 | .00135 | .00052 | .00026 |
| 20 | .00042 | .00106 | .00043 | .00078 | .00046 | .00039 | .00000 | .00036 | .00033 | .00019 | .00074 | .00126 | .00050 | .00036 | .00035 |
| 21 | .00330 | .00154 | .00242 | .00155 | .00110 | .01193 | .00000 | .00094 | .00044 | .00030 | .00132 | .00070 | .00138 | .00061 | .00141 |
| 22 | .02815 | .02769 | .01125 | .00938 | .02474 | .00935 | .00000 | .00559 | .00230 | .00315 | .01502 | .00387 | .02830 | .00733 | .01366 |
| 23 | .00986 | .00195 | .01153 | .01047 | .00909 | .00315 | .00000 | .14058 | .00281 | .00332 | .00502 | .00694 | .02700 | .00928 | .00212 |
| 24 | .00039 | .00271 | .00039 | .00063 | .00060 | .00055 | .00000 | .00147 | .00203 | .00177 | .00146 | .00120 | .00080 | .00065 | .00023 |
| 25 | .02618 | .02941 | .01948 | .03226 | .01289 | .01317 | .00000 | .00797 | .00688 | .00531 | .02300 | .00834 | .01689 | .00996 | .01219 |
| 26 | .31867 | .08462 | .01658 | .02821 | .03004 | .02221 | .00000 | .01652 | .01671 | .01442 | .04717 | .01647 | .02915 | .03291 | .01175 |
| 27 | .01233 | .00358 | .02360 | .00684 | .00835 | .00668 | .00000 | .01512 | .00337 | .00716 | .01138 | .00600 | .02205 | .00962 | .00817 |
| 28 | .00423 | .00057 | .00978 | .00344 | .00123 | .00229 | .00000 | .00200 | .00940 | .00160 | .00198 | .00086 | .00470 | .00137 | .00202 |
| 29 | .03763 | .03022 | .01655 | .02575 | .02317 | .03796 | .00000 | .01826 | .02552 | .02994 | .03116 | .03612 | .02275 | .01939 | .01712 |
| 30 | .09309 | .32328 | .14319 | .30904 | .19165 | .13888 | .00000 | .11155 | .10769 | .07897 | .26368 | .10890 | .18556 | .14283 | .09805 |

| | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .00215 | .00071 | .00097 | .00080 | .00082 | .00143 | .00074 | .00152 | .00110 | .00140 | .00101 | .00027 | .00067 | .01570 | .00584 |
| 2 | .00196 | .00203 | .00209 | .00887 | .00290 | .00727 | .00130 | .00330 | .00754 | .02147 | .00239 | .00073 | .00131 | .00357 | .00490 |
| 3 | .00180 | .00244 | .00238 | .00117 | .00696 | .00282 | .00011 | .00041 | .00181 | .00084 | .00020 | .00007 | .00009 | .00013 | .00028 |
| 4 | .00265 | .00120 | .00132 | .00108 | .00146 | .01054 | .27062 | .00567 | .00257 | .00397 | .01063 | .00302 | .00286 | .00371 | .00240 |
| 5 | .00159 | .00032 | .00111 | .00026 | .00047 | .02862 | .00511 | .00094 | .00115 | .01751 | .00108 | .00050 | .00031 | .00034 | .00090 |
| 6 | .00300 | .00159 | .00193 | .00165 | .00189 | .00379 | .00207 | .00532 | .00264 | .00205 | .00225 | .00073 | .00161 | .00521 | .01851 |
| 7 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 8 | .00022 | .00021 | .00088 | .00212 | .00518 | .00088 | .00031 | .00118 | .00527 | .00243 | .00030 | .00009 | .00018 | .00054 | .00095 |
| 9 | .00001 | .00000 | .00000 | .00001 | .00001 | .00001 | .00001 | .00001 | .00003 | .00001 | .00001 | .00000 | .00000 | .00002 | .00005 |
| 10 | .00017 | .00021 | .00011 | .00209 | .00014 | .00017 | .00010 | .00013 | .00047 | .00093 | .00040 | .00005 | .00010 | .00087 | .00059 |
| 11 | .00256 | .00303 | .00298 | .01843 | .00368 | .00987 | .00175 | .00290 | .01189 | .04450 | .00242 | .00124 | .00212 | .00355 | .00400 |
| 12 | .00003 | .00002 | .00002 | .00194 | .00035 | .00005 | .00003 | .00003 | .00004 | .00049 | .00007 | .00002 | .00003 | .00004 | .00015 |
| 13 | .00276 | .00342 | .00433 | .00278 | .00852 | .01840 | .00148 | .01073 | .01641 | .00502 | .00194 | .00061 | .00101 | .01063 | .00804 |
| 14 | .00318 | .00178 | .00207 | .00182 | .00243 | .00396 | .00233 | .00329 | .00429 | .00216 | .00463 | .00096 | .00182 | .00270 | .02979 |
| 15 | .39442 | .02964 | .03084 | .00447 | .00365 | .00155 | .00058 | .00047 | .00129 | .00294 | .00038 | .00010 | .00017 | .00019 | .00053 |
| 16 | .01620 | .02300 | .02020 | .01092 | .06604 | .00086 | .00059 | .00304 | .01684 | .00493 | .00071 | .00052 | .00041 | .00047 | .00161 |
| 17 | .00418 | .09361 | .03136 | .03936 | .03163 | .01058 | .00380 | .01398 | .00984 | .04662 | .00361 | .00139 | .00247 | .00364 | .00757 |
| 18 | .00386 | .00453 | .02608 | .00369 | .00212 | .00170 | .00164 | .00102 | .00190 | .00285 | .00111 | .00029 | .00062 | .00095 | .00584 |
| 19 | .00040 | .00146 | .00166 | .00850 | .00074 | .00040 | .00032 | .00034 | .00076 | .00084 | .00728 | .00009 | .00033 | .00048 | .00138 |
| 20 | .00051 | .00125 | .00583 | .00281 | .02068 | .00054 | .00047 | .00040 | .00170 | .00942 | .00246 | .00030 | .00057 | .00040 | .00200 |
| 21 | .00361 | .00076 | .00149 | .00114 | .00116 | .13664 | .00136 | .00219 | .00119 | .04252 | .00177 | .00108 | .00183 | .00061 | .00231 |
| 22 | .00372 | .00238 | .00259 | .00263 | .00326 | .02394 | .01050 | .01066 | .00772 | .01024 | .03303 | .00958 | .00849 | .01081 | .00711 |
| 23 | .00197 | .00322 | .00168 | .00494 | .01962 | .00734 | .00499 | .07093 | .01004 | .00619 | .00093 | .00030 | .00053 | .00103 | .00294 |
| 24 | .00043 | .00031 | .00038 | .00050 | .00115 | .00262 | .00166 | .00136 | .03525 | .00195 | .00094 | .00013 | .00026 | .00045 | .00189 |
| 25 | .01884 | .00732 | .00764 | .00756 | .00808 | .01505 | .02673 | .01403 | .00883 | .00656 | .03773 | .02512 | .04199 | .01074 | .04308 |
| 26 | .02021 | .01404 | .01672 | .01629 | .02298 | .02523 | .03010 | .02366 | .02167 | .01941 | .10716 | .00540 | .03307 | .04066 | .07265 |
| 27 | .02275 | .00584 | .00688 | .00586 | .00875 | .01508 | .00739 | .04541 | .00745 | .00320 | .00709 | .02765 | .00720 | .01078 | .00507 |
| 28 | .00325 | .00113 | .00098 | .00082 | .00107 | .00806 | .00318 | .00623 | .00104 | .00070 | .00070 | .00119 | .00033 | .00165 | .00103 |
| 29 | .09475 | .01941 | .03237 | .02340 | .02156 | .02931 | .01220 | .02187 | .02447 | .04101 | .02565 | .00483 | .01504 | .01656 | .05553 |
| 30 | .16672 | .09296 | .10559 | .09586 | .10700 | .19380 | .12136 | .15271 | .13467 | .11171 | .12505 | .04365 | .09507 | .14743 | .13164 |

Note: The factors along the diagonal (that is, the effect of a sector's growth on itself) should represent only the additional "circulation" effect. The model will attribute the full forecasted growth to the sector before calculating the additional "circulation" effects.

TABLE 3.16

SAMPLE MODEL OUTPUT

Forecast Year: 1990    Industrial Coefficient: 2

| | Node No. | Supply (MCM) Local | Upstream | Other | Total | Intake MCM | % | Consume MCM | % | Outflow MCM | Minimum Flow MCM | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| March 1936 | 3 | 0.23 | 0.00 | 0.00 | 0.23 | 0.34 | 146.5 | 0.18 | 78.4 | 0.05 | 0.00 | * |
| March 1936 | 4 | 0.23 | 0.00 | 0.00 | 0.23 | 0.69 | 301.4 | 0.10 | 44.0 | 0.13 | 0.00 | * |
| June 1936 | 12 | 7.19 | 0.00 | 0.00 | 7.19 | 12.41 | 172.5 | 8.38 | 116.5 | 0.00 | 0.00 | *** |
| July 1936 | 8 | 4.10 | 136.67 | 0.00 | 140.77 | 174.71 | 124.1 | 139.40 | 99.0 | 1.37 | 0.00 | * |
| July 1936 | 9 | 67.95 | 0.00 | 0.00 | 67.95 | 98.69 | 145.2 | 72.25 | 106.3 | 0.00 | 16.07 | ***** |
| July 1936 | 10 | 0.00 | 1.37 | 0.00 | 1.37 | 435.17 | %31871.4 | 346.39 | %25369.3 | 0.00 | 0.00 | *** |
| July 1936 | 12 | 11.60 | 0.00 | 0.00 | 11.60 | 12.42 | 107.0 | 8.38 | 72.2 | 3.22 | 0.00 | * |
| Aug. 1936 | 3 | 0.68 | 0.00 | 0.00 | 0.68 | 1.21 | 177.1 | 0.87 | 127.9 | 0.00 | 0.00 | *** |
| Aug. 1936 | 9 | 50.51 | 0.00 | 0.00 | 50.51 | 72.44 | 143.4 | 51.25 | 101.5 | 0.00 | 16.07 | ***** |
| Aug. 1936 | 10 | 0.00 | 162.98 | 0.00 | 162.98 | 306.26 | 187.9 | 243.26 | 149.3 | 0.00 | 0.00 | *** |
| Aug. 1936 | 11 | 27.99 | 0.00 | 0.00 | 27.99 | 45.00 | 160.8 | 33.89 | 121.1 | 0.00 | 0.00 | *** |
| Aug. 1936 | 12 | 4.40 | 0.00 | 0.00 | 4.40 | 8.84 | 200.9 | 5.52 | 125.4 | 0.00 | 0.00 | *** |
| Oct. 1936 | 1 | 35.57 | 0.00 | 0.00 | 35.57 | 4.50 | 12.6 | 0.86 | 2.4 | 34.71 | 42.85 | ***** |
| Nov. 1936 | 1 | 28.18 | 0.00 | 0.00 | 28.18 | 3.94 | 14.0 | 0.69 | 2.4 | 27.49 | 41.47 | ***** |
| Nov. 1936 | 4 | 0.37 | 0.00 | 0.00 | 0.37 | 0.68 | 184.9 | 0.10 | 26.5 | 0.27 | 0.00 | * |
| Nov. 1936 | 12 | 0.44 | 0.00 | 0.00 | 0.44 | 1.96 | 445.2 | 0.10 | 22.1 | 0.34 | 0.00 | * |
| Dec. 1936 | 1 | 7.28 | 0.00 | 0.00 | 7.28 | 3.98 | 54.7 | 0.70 | 9.7 | 6.58 | 42.85 | ***** |
| Dec. 1936 | 5 | 0.00 | 6.28 | 0.00 | 6.28 | 6.97 | 111.0 | 3.36 | 53.5 | 2.92 | 0.00 | * |
| Dec. 1936 | 9 | 19.34 | 0.00 | 0.00 | 19.34 | 9.94 | 51.4 | 1.81 | 9.4 | 17.53 | 32.14 | ***** |
| Dec. 1936 | 12 | 0.61 | 0.00 | 0.00 | 0.61 | 1.97 | 324.1 | 0.10 | 16.3 | 0.51 | 0.00 | * |
| Jan. 1937 | 1 | 8.04 | 0.00 | 0.00 | 8.04 | 3.98 | 49.5 | 0.78 | 9.7 | 7.26 | 42.85 | ***** |
| Jan. 1937 | 5 | 0.00 | 6.90 | 0.00 | 6.90 | 6.97 | 101.0 | 3.39 | 49.1 | 3.51 | 0.00 | * |
| Jan. 1937 | 9 | 27.23 | 0.00 | 0.00 | 27.23 | 9.94 | 36.5 | 1.88 | 6.9 | 25.35 | 32.14 | ***** |
| Jan. 1937 | 12 | 0.46 | 0.00 | 0.00 | 0.46 | 1.97 | 432.1 | 0.11 | 23.9 | 0.35 | 0.00 | * |
| Feb. 1937 | 1 | 7.06 | 0.00 | 0.00 | 7.06 | 3.86 | 54.7 | 0.66 | 9.4 | 6.39 | 38.71 | ***** |
| Feb. 1937 | 5 | 0.00 | 6.12 | 0.00 | 6.12 | 6.95 | 113.6 | 3.35 | 54.8 | 2.77 | 0.00 | * |
| Feb. 1937 | 9 | 24.93 | 0.00 | 0.00 | 24.93 | 9.81 | 39.4 | 1.77 | 7.1 | 23.16 | 29.03 | ***** |
| March 1937 | 1 | 18.35 | 0.00 | 0.00 | 18.35 | 3.98 | 21.7 | 0.70 | 3.8 | 17.65 | 42.85 | ***** |
| April 1937 | 12 | 1.76 | 0.00 | 0.00 | 1.76 | 2.02 | 114.8 | 0.11 | 6.2 | 1.65 | 0.00 | * |
| May 1937 | 12 | 1.14 | 0.00 | 0.00 | 1.14 | 5.47 | 480.5 | 2.82 | 247.8 | 0.00 | 0.00 | *** |
| June 1937 | 12 | 1.61 | 0.00 | 0.00 | 1.61 | 12.41 | 768.5 | 8.38 | 518.9 | 0.00 | 0.00 | *** |
| July 1937 | 3 | 0.46 | 0.00 | 0.00 | 0.46 | 1.58 | 346.8 | 1.17 | 256.8 | 0.00 | 0.00 | *** |
| July 1937 | 10 | 0.00 | 327.20 | 0.00 | 327.20 | 435.17 | 133.0 | 346.39 | 105.9 | 0.00 | 0.00 | *** |
| July 1937 | 11 | 12.67 | 0.00 | 0.00 | 12.67 | 62.32 | 492.1 | 47.75 | 377.0 | 0.00 | 0.00 | *** |
| Aug. 1937 | 10 | 0.00 | 266.91 | 0.00 | 266.91 | 306.26 | 114.7 | 243.26 | 91.1 | 23.65 | 0.00 | * |
| Aug. 1937 | 12 | 8.27 | 0.00 | 0.00 | 8.27 | 8.84 | 106.9 | 5.52 | 66.7 | 2.75 | 0.00 | * |
| Oct. 1937 | 12 | 3.19 | 0.00 | 0.00 | 3.19 | 3.51 | 110.1 | 1.29 | 40.5 | 1.89 | 0.00 | * |
| Nov. 1937 | 1 | 36.77 | 0.00 | 0.00 | 36.77 | 3.94 | 10.7 | 0.69 | 1.9 | 36.08 | 41.47 | ***** |
| Nov. 1937 | 12 | 0.44 | 0.00 | 0.00 | 0.44 | 1.96 | 445.2 | 0.10 | 22.1 | 0.34 | 0.00 | * |
| Dec. 1937 | 1 | 21.31 | 0.00 | 0.00 | 21.31 | 3.98 | 18.7 | 0.70 | 3.3 | 20.61 | 42.85 | ***** |
| Dec. 1937 | 3 | 0.15 | 0.00 | 0.00 | 0.15 | 0.34 | 222.7 | 0.18 | 117.6 | 0.00 | 0.00 | *** |
| Dec. 1937 | 4 | 0.15 | 0.00 | 0.00 | 0.15 | 0.69 | 452.1 | 0.10 | 66.0 | 0.05 | 0.00 | * |
| Dec. 1937 | 12 | 0.46 | 0.00 | 0.00 | 0.46 | 1.97 | 432.1 | 0.10 | 21.8 | 0.36 | 0.00 | * |
| Jan. 1938 | 1 | 21.54 | 0.00 | 0.00 | 21.54 | 3.98 | 18.5 | 0.78 | 3.6 | 20.76 | 42.85 | ***** |
| Jan. 1938 | 12 | 0.46 | 0.00 | 0.00 | 0.46 | 1.97 | 432.1 | 0.11 | 23.9 | 0.35 | 0.00 | * |
| Feb. 1938 | 1 | 12.06 | 0.00 | 0.00 | 12.06 | 3.86 | 32.0 | 0.66 | 5.5 | 11.39 | 38.71 | ***** |
| March 1938 | 1 | 32.23 | 0.00 | 0.00 | 32.23 | 3.98 | 12.4 | 0.70 | 2.2 | 31.53 | 42.85 | ***** |
| May 1938 | 12 | 1.14 | 0.00 | 0.00 | 1.14 | 5.47 | 480.5 | 2.82 | 247.8 | 0.00 | 0.00 | *** |
| June 1938 | 3 | 0.73 | 0.00 | 0.00 | 0.73 | 1.58 | 214.9 | 1.17 | 159.1 | 0.00 | 0.00 | *** |
| Aug. 1938 | 10 | 28.44 | 245.52 | 0.00 | 273.96 | 306.26 | 111.8 | 243.26 | 88.8 | 30.70 | 0.00 | * |
| Sept. 1938 | 12 | 3.23 | 0.00 | 0.00 | 3.23 | 3.56 | 110.3 | 1.30 | 40.3 | 1.93 | 0.00 | * |
| Oct. 1938 | 12 | 1.82 | 0.00 | 0.00 | 1.82 | 3.51 | 192.6 | 1.29 | 71.0 | 0.53 | 0.00 | * |
| Nov. 1938 | 1 | 23.85 | 0.00 | 0.00 | 23.85 | 3.94 | 16.5 | 0.69 | 2.9 | 23.16 | 41.47 | ***** |

Table 3.16
Sample Model Output - 2

Forecast Year: 1990
Ind'l Coefficient: 2

| Gauge | Name | Month | Number of Occurrences Total | 0 - 10 % | 10 - 20 % | 20 - 30 % | 30 - 40 % | 40 - 50 % | 50 - 60 % | 60 - 70 % | 70 - 80 % | 80 - 90 % | 90 - 100 % | No Supply |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 05AD007 | Lethbridge | Jan. | 56 | 25 | 30 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Feb. | 56 | 15 | 32 | 7 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | March | 56 | 41 | 14 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | April | 56 | 54 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | May | 56 | 50 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | June | 56 | 40 | 10 | 2 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | July | 56 | 5 | 17 | 9 | 5 | 7 | 1 | 4 | 4 | 1 | 3 | 0 |
| | | Aug. | 56 | 0 | 3 | 6 | 6 | 10 | 7 | 2 | 8 | 8 | 6 | 0 |
| | | Sept. | 56 | 3 | 9 | 13 | 15 | 11 | 4 | 1 | 0 | 0 | 0 | 0 |
| | | Oct. | 56 | 15 | 16 | 13 | 10 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| | | Nov. | 56 | 53 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Dec. | 56 | 46 | 9 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Intake | Total | 672 | 347 | 148 | 53 | 40 | 32 | 12 | 9 | 12 | 10 | 9 | |
| | | Jan. | 56 | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Feb. | 56 | 55 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | March | 56 | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | April | 56 | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | May | 56 | 53 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | June | 56 | 45 | 7 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | July | 56 | 15 | 15 | 8 | 5 | 5 | 4 | 1 | 2 | 0 | 1 | 0 |
| | | Aug. | 56 | 1 | 9 | 10 | 10 | 7 | 9 | 6 | 2 | 1 | 1 | 0 |
| | | Sept. | 56 | 12 | 25 | 16 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Oct. | 56 | 32 | 20 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Nov. | 56 | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Dec. | 56 | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Consumption | Total | 672 | 493 | 80 | 38 | 21 | 13 | 13 | 7 | 4 | 1 | 2 | |
| | | Jan. | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | |
| | | Feb. | 56 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | |
| | | March | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | |
| | | April | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | May | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | June | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | July | 56 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | Aug. | 56 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | |
| | | Sept. | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | Oct. | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | Nov. | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | Dec. | 56 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | |
| | Minimum Flow | Total | | 2 | 0 | 1 | 0 | 2 | 0 | 0 | 2 | 2 | 0 | |

This implies that all of the water is being used at least once which may or may not be a problem depending on the spatial distribution of water users in the subbasin. If the users are well distributed throughout the subbasin, then return flows from upstream users will likely satisfy downstream needs. If the users are concentrated in a city for example, return flows may not be available for reuse and therefore a ratio approaching 1.0 could be an indicator of water shortages.

One example of reuse which is currently inherent in the model is that of hydroelectric generating plants. On a river system with a large number of hydro plants, the ratio of intake to supply may exceed 1.0 many times and yet the full water resource remains available for further use.

In general, if gross intake exceeds availability in a subbasin in a number of years, the user should examine the distribution and type of water use in more detail to establish whether or not a shortage exists and its extent.

(b) If the ratio of consumption to supply approaches 1.0 in any month.

The consumption-to-supply ratio is a much more reliable indicator of the severity of a water shortage problem. Obviously, if this ratio approaches 1.0 in any month, rationing of the water resource will be necessary. The model is currently programmed to flag any months in the analysis where the consumption-to-supply ratio exceeds 0.70.

(c) Frequency of occurrence.

If the occurrence of either of the above conditions [(a) or (b)] is rare, then it is possible that some form of rationing would effectively manage the water shortage. However, if shortages occur frequently, say, approaching one every 2 years, then the problem is becoming more severe.

# 4 - REQUIREMENTS FOR OPERATION

## 4.1 - Hardware and Software

The program is designed to run on the IBM-PC with a minimum of 128K bytes of memory. One disk drive is essential, although two are recommended because of the volume of data used in the model. It runs on Disk Operating System (DOS) version 1.1 and is programmed in IBM's standard BASIC (developed by Microsoft). No special functions are employed so it will be convertible to most other versions of BASIC without major difficulty. Graphics are not employed.

Although an 80-column screen is used for display, the program could be modified for a 40-column screen. A 15-in. wide printer is required, capable of printing in compressed mode (16 characters/in.) to ensure the program input will fit on the page.

## 4.2 - User Expertise

Loading and running the model can be performed in a routine manner. However, because of the large amount of different data that is included in the system, it would be difficult for an inexperienced user to generate useful results. The user must fully understand the manipulation of the various data files, the use of the IBM-PC's Disk Operating System to copy and print data files, and the use of a screen editor program (such as Volkswriter) to edit files.

When originally designing the program, it was recognized that the amount of data to be processed would be substantial. An interactive or "user-friendly" program that would prompt the user for all input data would be too tedious for the loading of data. The user must therefore develop an understanding of the file structure so that data changes can be made directly in the files.

## 5 - FUTURE MODEL IMPROVEMENTS

The Water Use Model has been developed in a modular format to facilitate enhancement of certain model components as funds become available.

Specific areas where improvements are warranted are discussed in the following sections.

### (a) Agricultural Submodel

In the western provinces, agriculture is by far the largest water user and is also the user with the greatest variability of demand. This variability results from precipitation and evapotranspiration differences from one region to another as well as different cropping patterns. Documented data on actual water use by different crops or even gross water use within a given irrigation district are sparse as demonstrated in Appendix A. It is therefore necessary to develop a submodel which will compute water use by crop given the basic climatological parameters such as precipitation and solar radiation. This will substantially improve the accuracy of the model and permit taking into account any correlation between flow and irrigation demand.

### (b) Reservoir Regulation Submodel

The model does not currently have the ability to simulate man-made reservoirs. This facility would be a major asset because

- fully naturalized streamflow records, where available, usually have the effects of reservoir regulation removed and could then be used directly. Reservoir regulation effects would be resimulated using the model.

- the facility would permit the evaluation of impact of additional reservoir storage on regions with water shortages.

(c) Groundwater Submodel

The model, as it exists, does not have a facility for modeling the monthly water available from groundwater sources. The model would be enhanced, however, if groundwater aquifers were simulated in a manner similar to that planned for storage reservoirs. It is intended that future model development include a submodel capable of simulating specific aquifers and their limitations, as well as maximum withdrawal and recharge rates. As a part of this development use, federal and provincial data banks will be studied.

(d) Water Quality Submodel

Even though an analysis using the Water Use Model shows that sufficient water is available to satisfy demands, the quality may not be of sufficiently high standard. A water quality submodel would examine the expected chemical and biochemical loadings from the various industrial sectors on the available water resource to determine if government standards are likely to be exceeded or not.

# 6 - TEST CASE RESULTS

## 6.1 - Introduction

The test case presented in this section is intended to be used as an introduction to the application and capabilities of the Water Use Forecasting Model. Variations in water use coefficients and future development scenarios are investigated for the test basin. The chosen scenarios are intended to illustrate the flexibility of the model for analyzing the impacts of almost any conceivable development scheme. The various scenarios which were analyzed demonstrate the potential of the model for identifying possible future water use problems. The sensitivity of the resulting water use problems to variations in future development and water use rates have also been analyzed.

The South Saskatchewan River Basin was chosen for demonstration purposes because it is universally recognized that this region of Canada currently has water-related conflicts. The Beaver River Basin near Cold Lake was also chosen for analysis because of its potential for development of specific energy-related projects in the future. It is presently anticipated that future development in these basins will require imaginative planning, utilizing new technologies, to prevent an increasing occurrence of water deficits. The Water Use Forecasting Model is viewed as a comprehensive planning tool which can provide substantial assistance in the planning exercise.

The following subsections describe the drainage basins, explain the evaluation strategy, the data used, and the results which were obtained from the Water Use Forecasting Model.

### 6.2 - Characteristics of the Test Basins

The South Saskatchewan River Basin contains four main subbasins which were analyzed separately--the Red Deer, the Bow, the Oldman and the lower South Saskatchewan basin itself. The Beaver River, which is part of the Churchill River system, is also analyzed. Maps showing the location of the subbasins are presented in Figures 6.1 and 6.2 and a brief description of each is given in the following section.

#### 6.2.1 - The Red Deer River Subbasin

The Red Deer River subbasin is located in central Alberta and is the most northerly major tributary of the South Saskatchewan River. The basin extends from the Rocky Mountains to a point just inside Saskatchewan and is consequently comprised of topography which varies from foothills to prairie plains. The 50 000-$km^2$ basin is interspersed with rivers and shallow lakes.

The major population center of the basin is the city of Red Deer which contains approximately 25 percent of the subbasin population. The historic population growth has been moderate and averaged 1.3 percent/yr from 1951 to 1978. The rural population declined somewhat during this same period but was primarily stabilized due to the expansion of ranching activity.

Agriculture and mineral extraction are the major economic activities of the subbasin. The agricultural activity is primarily ranching, although there is some irrigation of field crops near the city of Red Deer. Oil and gas production and coal extraction dominate the mining activities. The

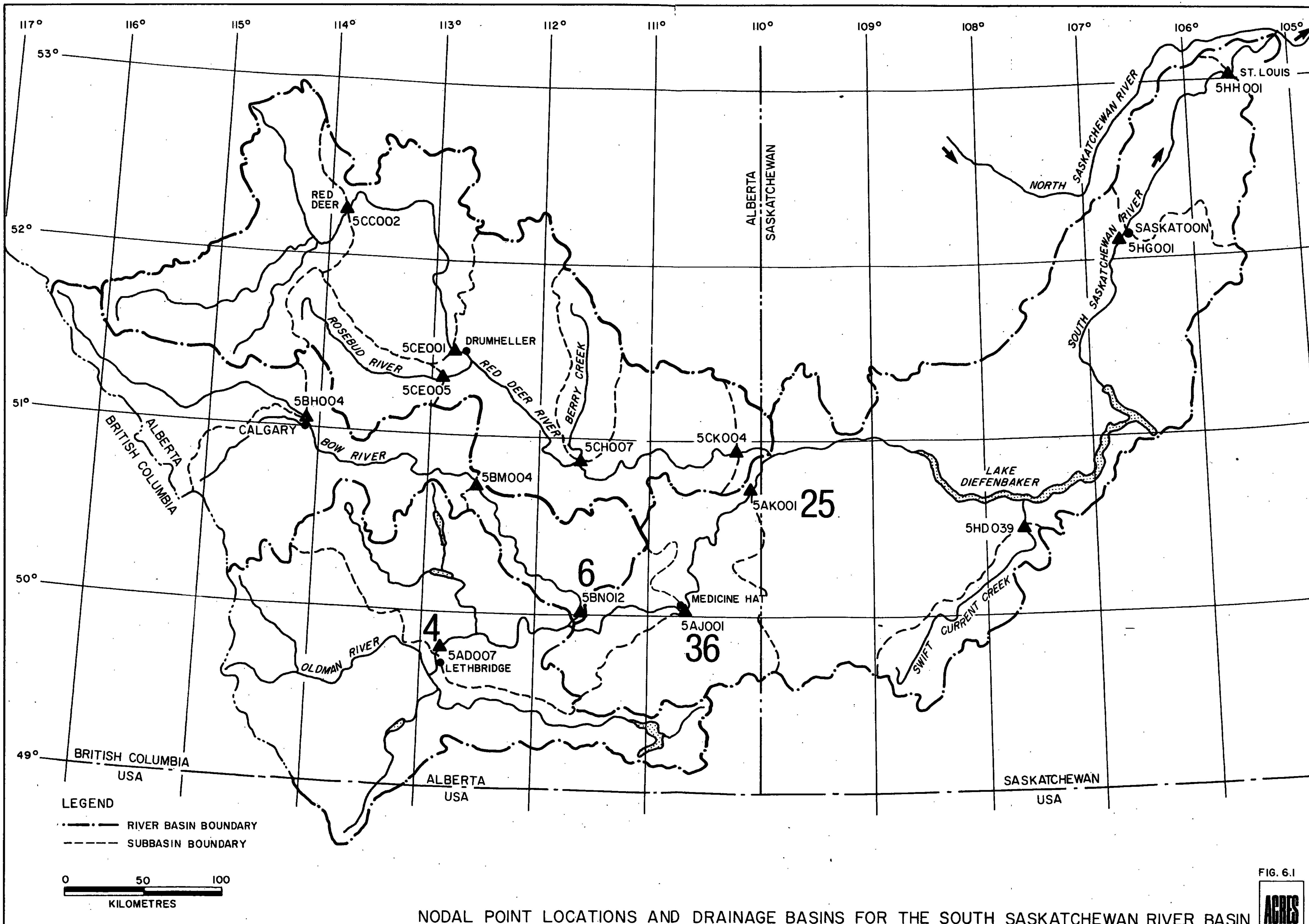



FIG. 6.1

NODAL POINT LOCATIONS AND DRAINAGE BASINS FOR THE SOUTH SASKATCHEWAN RIVER BASIN

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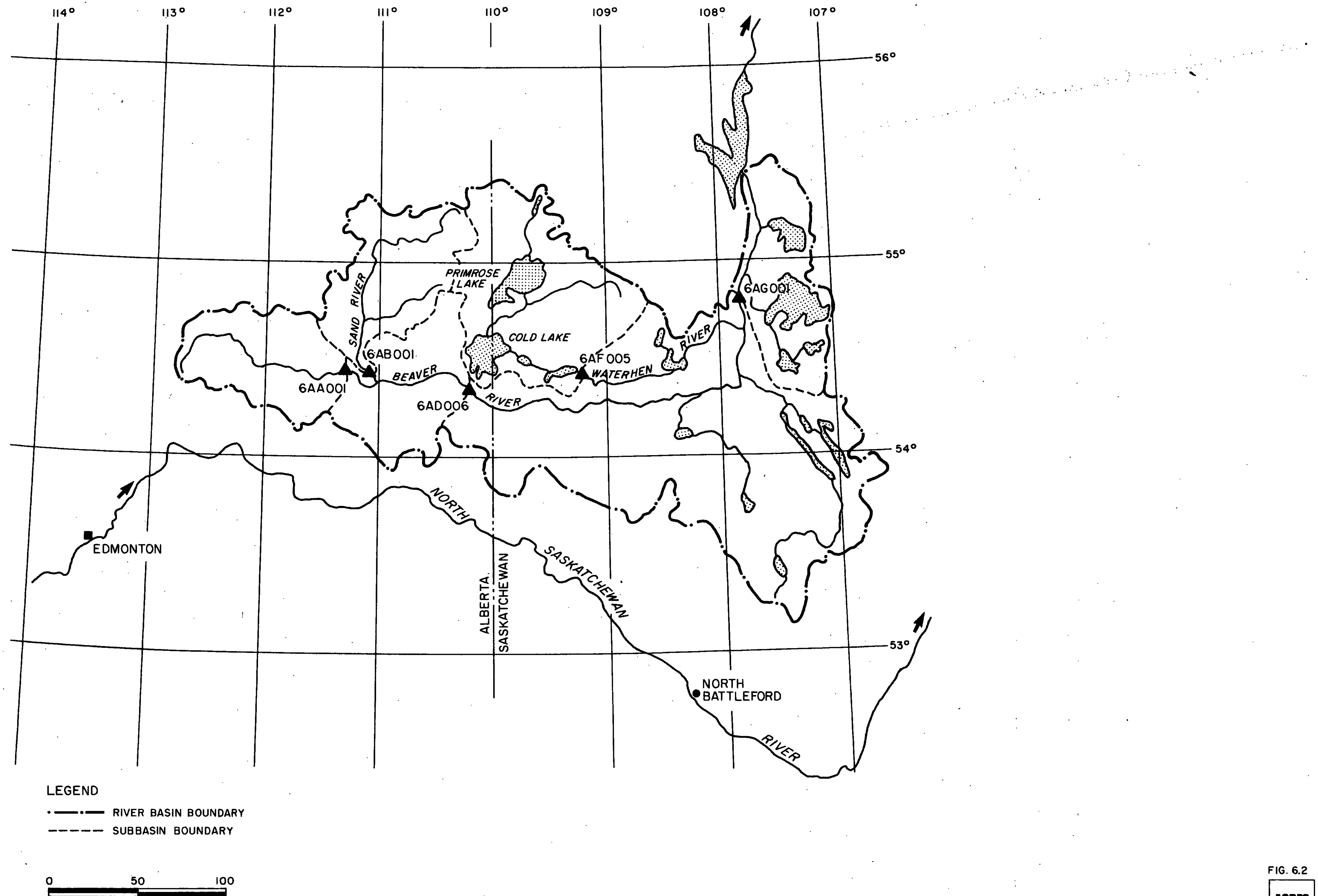



NODAL POINT LOCATIONS AND DRAINAGE BASINS FOR THE BEAVER RIVER BASIN food and beverage industries and petroleum and coal products industries dominate the manufacturing sector.

Within the Red Deer River subbasin, five nodes (as listed below) were used for analysis in the model.

05CC002 - Red Deer River at Red Deer
05CE001 - Red Deer River at Drumheller
05CH007 - Berry Creek near mouth
05CE005 - Rosebud River near Redland
05CK004 - Red Deer River near Blindloss

The schematic interconnection of these nodes is shown in Figure 6.3 and the location of the nodes is shown in Figure 6.1.

### 6.2.2 - The Bow River Subbasin

The Bow River is the central tributary of the South Saskatchewan River in Alberta and it flows eastward from the Rocky Mountains where it joins the Oldman River and forms the South Saskatchewan River. The drainage area of 25 600 $km^2$ has a varied topography ranging from foothills to the Alberta plateau.

The major population center of the basin is Calgary which contains just over 90 percent of the subbasin population. During the period 1951 to 1978 the average subbasin population growth rate was 4.4 percent/yr, with the majority of the growth occurring in Calgary. The rural population increased marginally. The industrial activities of this subbasin are concentrated in oil, gas and coal extraction and related industries. The food and beverage industries and chemical and other related products industries have secondary significance. Agriculture within this subbasin is concentrated in

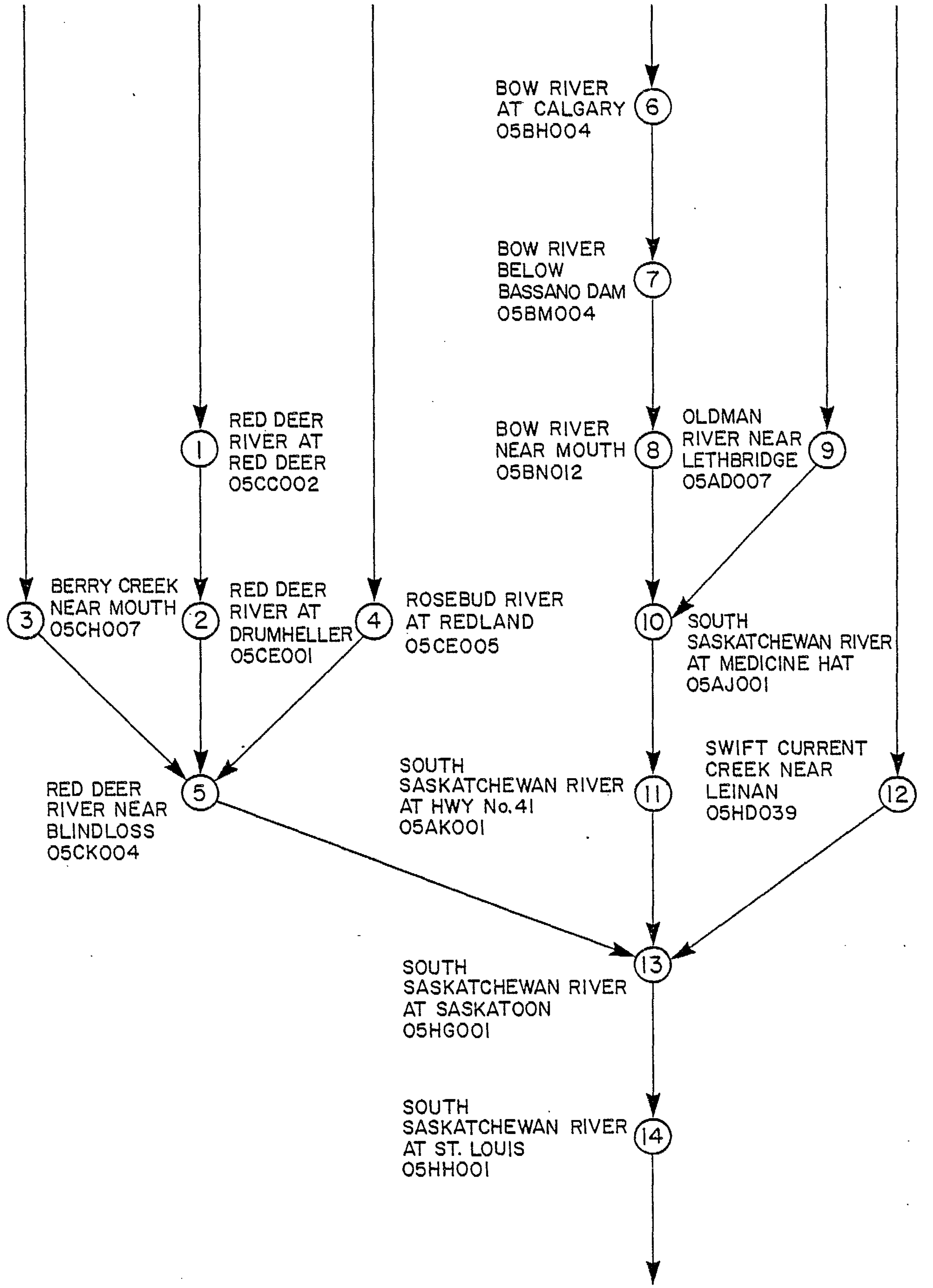



FIG. 6.3

SOUTH SASKATCHEWAN RIVER NETWORK

ACRES

that portion of the basin below Calgary. There are major areas of both irrigated and nonirrigated crops, as well as major ranching activities.

Within the Bow River subbasin, three nodes (as listed below) were used for analysis. The schematic interconnection of these nodes is shown in Figure 6.3 and the location of the node is shown in Figure 6.1.

05BH004 - Bow River at Calgary
05BM004 - Bow River below Bassano dam
05BN012 - Bow River near mouth

6.2.3 - The Oldman River Subbasin

The Oldman River is located in southwest Alberta and its drainage basin extends from the United States-Canada boundary north to the Bow River subbasin and from the Rocky Mountains to the Alberta plateau. The drainage area of 27 500 $km^2$ includes the Oldman River and four major tributaries.

The city of Lethbridge is the major population center and contains over 50 percent of the subbasin population. During the period 1951 to 1978 the subbasin experienced a very moderate growth rate of 1.2 percent/yr. The rural population decreased slightly while the urban population increased at approximately twice the average growth rate.

Mineral extraction, manufacturing and agriculture are the major economic activities within the subbasin. The minerals extraction sector involves natural gas, petroleum and coal. The manufacturing sector is primarily food-related packing, processing, and transportation equipment manufacturing. Agriculture in this basin is as diverse as for the Bow River and includes ranching and nonirrigated and irrigated crop production.

The Oldman River subbasin was analyzed as one node at Lethbridge (Gauge 05AD007). The portion of the river basin below Lethbridge was included in the first South Saskatchewan River nodal point which is located at Medicine Hat. The relation of the Oldman River nodal point to other nodes in the system is shown in Figure 6.3 and the location of this model point is shown in Figure 6.1.

### 6.2.4 - The South Saskatchewan River Subbasin

The South Saskatchewan River subbasin drains approximately 70 000 $km^2$ in southern Alberta and western Saskatchewan. The topography varies from the Alberta plateau to the Saskatchewan plains with an elevation difference of 100 to 150 m. The major tributaries of the subbasin are the Oldman, Bow and Red Deer rivers which have already been discussed. The major Saskatchewan tributary is Swift Current Creek which is handled as a separate node within the network.

Approximately 75 percent of the population of this subbasin is urban. During the period 1951 to 1978, this subbasin experienced an overall growth rate of 1.6 percent/yr. The rural population decreased at a rate of 1 percent/yr while the urban population increased by 3 percent/yr.

The mining of potash, the petroleum industry, the chemical industry and food processing are the major economic activities. Agriculture consists of extensive tracts of both irrigated and nonirrigated crop land.

The South Saskatchewan River subbasin was analyzed using five nodal locations as listed on the following page.

05AJ001 - South Saskatchewan at Medicine Hat
05AK001 - South Saskatchewan at Highway 41
05HD039 - Swift Current Creek near Leinan
05HG001 - South Saskatchewan at Saskatoon
05HH001 - South Saskatchewan at St. Louis

Four of these nodes are located along the main river while one is located near the mouth of Swift Current Creek. The schematic interconnection of these nodes is shown in Figure 6.3 and the location of the nodes is shown in Figure 6.1.

### 6.2.5 - The Beaver River Basin

The Beaver River is located in east central Alberta and west central Saskatchewan. The river drains approximately 45 000 $km^2$ northeastward to the Churchill River and includes the Waterhen and Sand rivers, as well as the Cold Lake area on the Alberta-Saskatchewan border.

Approximately 45 percent of the basin population is urban and is scattered throughout small communities. The area is sparsely populated with a current population of about 40 000 people.

The major economic activities of the basin include forestry and related wood products industries, oil and gas production, and food and beverage processing. The agriculture of the basin is primarily beef ranching with some nonirrigated and very little irrigated field crop production.

The Beaver River Basin was analyzed using five nodal points. The schematic interconnection of these nodes is shown in Figure 6.4 and the location of the nodes is shown in Figure 6.2.

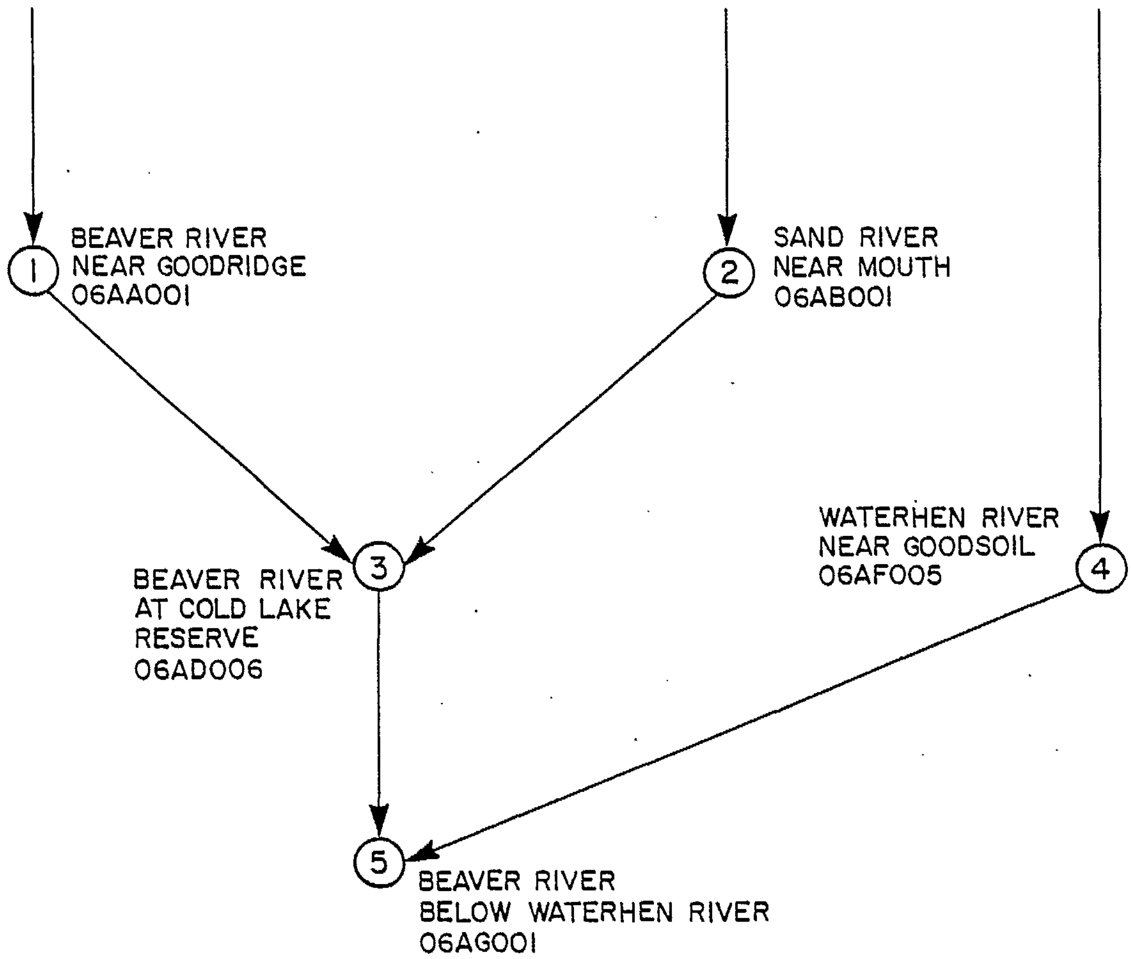



FIG. 6.4

BEAVER RIVER NETWORK

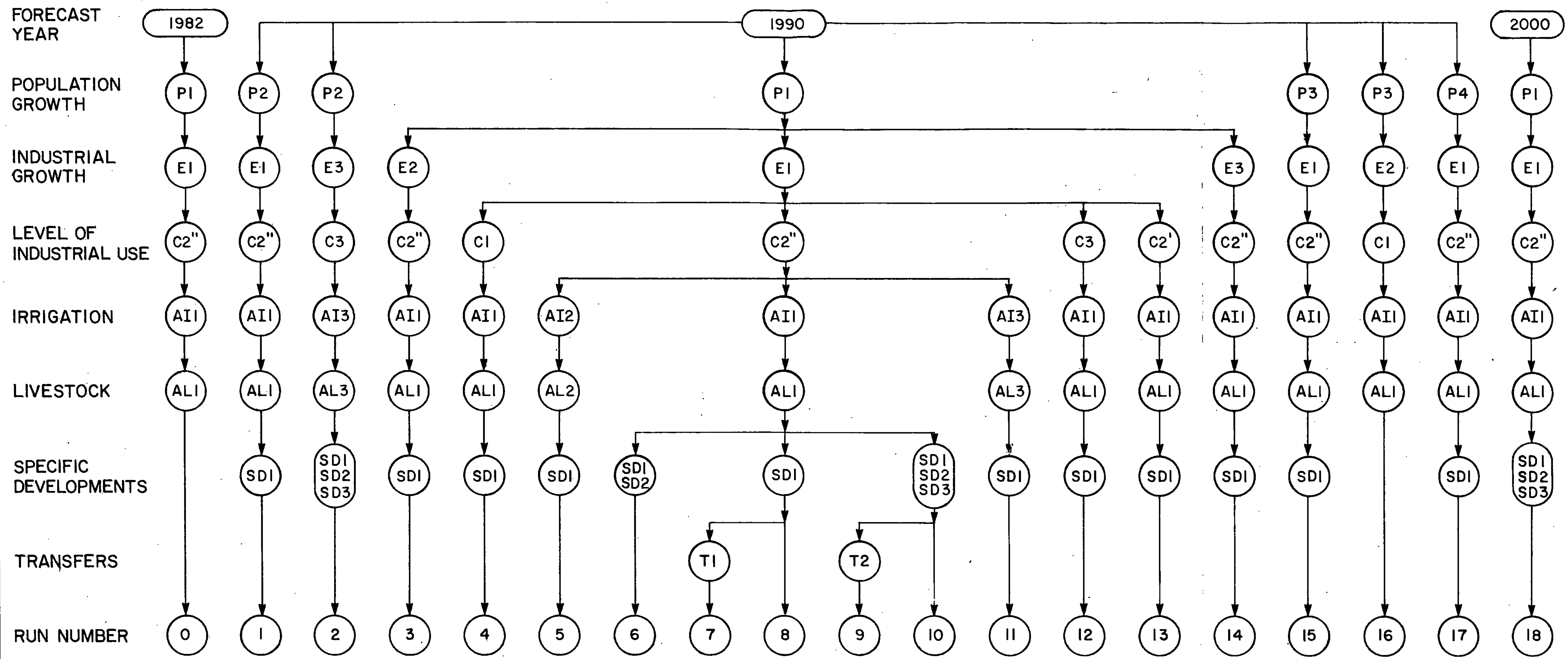
## 6.3 - Evaluation Strategy

The water use model will normally be used to answer specific questions and, consequently, the evaluation strategy must be organized accordingly. In the current test case, a series of questions have been asked which relate to both the operation and sensitivity of the model, as well as to specific water-related planning issues. The purpose of examining such a wide range of questions is to demonstrate the flexibility of the model. The general approach to this study would be similar to any preliminary evaluation strategy for a particular basin.

The South Saskatchewan River was analyzed for a wide range of questions requiring 19 different runs of the computer model. The Beaver River was analyzed for 5 scenarios that were felt to be the most significant considering the current level of development and settlement in the basin. These two sets of analyses are discussed in the following subsections.

### 6.3.1 - The South Saskatchewan River Basin

The issues which were addressed in the study generally relate to establishing the effect of changes in different variables on the overall water resource utilization within the sub-basins. The individual issues or questions studied are documented below. The run numbers refer to Figure 6.5 which shows the overall evaluation strategy and the various variables studied. The majority of the runs examined a 1990 forecast year; however, one run was made for each of 1982 and 2000 in order to document the present condition and a long-range forecast, respectively.




## LEGEND

| | |
|---|---|
| P1 | FERTILITY INCREASE AND SOME MIGRATION |
| P2 | FERTILITY INCREASE AND MORE MIGRATION |
| P3 | FERTILITY DECREASE AND SOME MIGRATION |
| P4 | FERTILITY DECREASE AND MORE MIGRATION |
| E1 | ECONOMIC COUNCIL OF CANADA |
| E2 | U OF T NATIONAL FORECAST |
| E3 | U OF T WESTERN FORECAST |
| C1 | LOW USE DEFAULT COEFFICIENTS |
| C2' | EXPECTED USE DEFAULT COEFFICIENTS |
| C2" | CALIBRATED USE COEFFICIENTS |
| C3 | HIGH USE DEFAULT COEFFICIENTS |
| AI1 | GROWTH IN IRRIGATION - LOW (EXPECTED) |
| AI2 | GROWTH IN IRRIGATION - MEDIUM |
| AI3 | GROWTH IN IRRIGATION - HIGH |
| AL1 | GROWTH IN LIVESTOCK POPULATION - LOW |
| AL2 | GROWTH IN LIVESTOCK POPULATION - MEDIUM |
| AL3 | GROWTH IN LIVESTOCK POPULATION - HIGH |
| SD1 | SPECIFIC DEVELOPMENTS - PLANNED 1980-1988 |
| SD2 | SPECIFIC DEVELOPMENTS - PLANNED 1989-1993 |
| SD3 | SPECIFIC DEVELOPMENTS - PLANNED 1994-2000 |
| T1 | TRANSFER NODE TO NODE WITHIN STUDY BASIN |
| T2 | TRANSFER EXTERNAL NODE TO INTERNAL NODE |

| QUESTION ADDRESSED | RELEVANT RUN NUMBERS |
|---|---|
| POPULATION GROWTH | 1, 8, 15, 17 |
| INDUSTRIAL GROWTH | 3, 8, 14 |
| LEVEL OF INDUSTRIAL USE | 4, 8, 12, 13 |
| AGRICULTURAL GROWTH | 5, 8, 11 |
| SPECIFIC DEVELOPMENTS | 6, 8, 10 |
| TRANSFERS | 7, 8 AND 9, 10 |
| DEVELOPMENT WITH TIME | 0, 8, 18 |
| "GREATEST" AND "LEAST" USE | 2, 16 |

FIG. 6.5

ALTERNATIVE TEST CASE SCENARIOS FOR THE SOUTH SASKATCHEWAN RIVER

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(a) Examine the effects of each of 4 population growth scenarios with all other factors being equal. Runs 1, 8, 15 and 17.

(b) Examine the effects of each of 3 economic growth scenarios using only the first population growth scenario (fertility increase plus some migration) and all other factors as used in (a) above. Runs 3, 8 and 14.

(c) Examine the effects of each of 4 industrial water use coefficient data sets--a high, expected, and low forecast and a set calibrated to current basin-specific data. For these scenarios all other factors are as used for the previous cases [(a) and (b) above]. All 4 variations were tested using a single selected population growth scenario and the Economic Council of Canada economic growth scenario. Runs 4, 8, 12 and 13.

(d) Examine the effects of each of 3 agricultural growth scenarios--low (expected), medium and high. Although it is possible to vary the growth rates between irrigation and livestock, for test purposes it was assumed that both factors would vary in the same manner. Other factors were as noted in Figure 6.5. Runs 5, 8 and 11.

(e) Examine the effects of 3 specific development scenarios. The specific developments which were included are those energy-related water uses which were identified and documented in the Phase I segment of the current study. The specific developments were divided into three categories

- SD1: those planned for the period 1980 - 1988
- SD2: those planned for the period 1989 - 1993
- SD3: those planned for the period 1994 - 2000.

Table 6.1 lists the specific developments which are planned for each nodal point. These developments and the water use coefficients associated with them were originally documented in the Phase 1 report of the current study. (Water Supply Constraints to Energy Development - Phase I, 1982, Reference 1). Only a single water use coefficient has been examined for each specific development.

The first scenario assumed that in 1990 only SD1 projects would be active. The second scenario assumed that SD1 projects would be active as well as SD2 projects which were moved ahead in time to be on-line by 1990. The third scenario was similar, and included SD3 projects as well as SD1 and SD2 projects. Other factors were as noted in Figure 6.5, Runs 6, 8 and 10.

(f) The two possible types of water transfer were studied.

- Transfers from node to node within a specific network. These transfers will not significantly affect supplies downstream from the junction of the two subbasins. The specific transfer tested was from the Red Deer River (Gauge 05CE001) to the Bow River (Gauge 05BM004). The transfer was 20 $m^3/s$ for June, July and August, and 5 $m^3/s$ in May and September. This was Run 7 and it compares directly to Run 8, except for the effect of the transfer.

- Transfers from an external node to a node within the network. These transfers will affect the total supply within the total basin. The specific transfer tested was from the North Saskatchewan River to the Red Deer River Basin (Gauge 05CC002). The transfer was 10 $m^3/s$ from November to March and 5 $m^3/s$ in

TABLE 6.1

SPECIFIC DEVELOPMENT DATA*

| Nodal Point | River Name | Type of Project | Project Name | Project Code | Location | Staging | Category | Water Consumption ($m^3/s$) | Production of Energy Production |
|---|---|---|---|---|---|---|---|---|---|
| 05CC002 | Red Deer | Coal mine | Open pit coal mine | A21 | Red Deer | 1991 | SD2 | 0.20 | 9 million t/yr |
| 05CC002 | Red Deer | Themal power | Thermal power plant | A57 | Red Deer | 1991 | SD2 | 3.0 | 2 000 MW |
| 05CE001 | Red Deer | Thermal power | Ardley | A53 | 140 km south of Edmonton | ?** | SD3 | 2.44 | 1 500 MW |
| 05CE001 | Red Deer | Thermal power | Trochu-Three Hills | A54 | 200 km south of Edmonton | ?** | SD3 | 0.82 | 750 MW |
| 05CE001 | Red Deer | Thermal power | Fording plant | A67 | Alix | 1993 | SD2 | 3.0 | 2 000 MW |
| 05CH007 | Berry Creek | Coal mine | Rose Lynn | A2 | Sheerness area | 1985 | SD1 | 0.024 | 1.1 million t/yr |
| 05CH007 | Berry Creek | Coal mine | Sheerness | A11 | Drumheller area | 1986 | SD1 | 0.033 | 1.5 million t/yr |
| 05CK004 | Red Deer | Thermal power | Sheerness | A52 | Hanna | 1985 | SD1 | 1.22 | 750 MW |
| 05BH004 | Bow River | Oil refinery | Turbo Resources Limited | A62 | Balzac, north of Calgary | 1983 | SD1 | 0.059 | 31 500 bbl/d |
| 05BH004 | Bow River | Oil refinery | Shell (grease plant) | A68 | Calgary | 1981 | SD1 | 0.0001 | 74 bbl/d |
| 05BM004 | Bow River | Coal mine | Cleichen thermal coal | A23 | Cleichen | 1987 | SD1 | 0.4** | ?** |
| 05BN012 | Bow River | Thermal power | Blackfoot | A55 | 200 km east of Edmonton | 1992 to 2001 | SD3) | 4.05 | 1 500 MW |
| 05BN012 | Bow River | Thermal power | Bow City - Kitsim | A56 | 120 km northwest of Medicine Hat | 1999 to 2001 | SD3) | | 1 000 MW |
| 05AD007 | Oldman River | Coal mine | Shaughnessy | A4 | Northwest of Lethbridge | 1985 | SD1 | 0.059 | 2.7 million t/yr |
| 05AD007 | Oldman River | Coal mine | Kipp | A5 | Lethbridge area | 1985 | SD1 | 0.022 | 1.0 million t/yr |
| 05AD007 | Oldman River | Coal slurry pipeline | Coleman-Blairmore | A24 | Coleman-Blairmore | ?** | SD3 | 0.5 | 13 million t/yr |
| 05AJ001 | South Saskatchewan | Methanol | Medicine Hat | A59 | Medicine Hat | 1982 | SD1 | 0.042 | 1 200 t/d |
| 05HG001 | South Saskatchewan | Thermal power | Grain and lignite | 518 | New Bridgeford | 1988 to 2000 | SD3 | 0.66 | 8 500 GW·h/y |
| 06AB001 | Sand | Oil production | BP Canada | A36 | 40 km north of Bonnyville | ?** | SD3 | 0.41 | 40 000 bbl/d |
| 06AD006 | Beaver | Oil production | Cold Lake - Esso | A34 | Cold Lake area | 1986 to 1988 | SD1 | 1.07 | 105 000 bbl/d |
| 06AD006 | Beaver | Oil production | Cold Lake - Esso | A34 | Cold Lake area | 1989 | SD2 | 0.36 | 35 000 bbl/d |
| 06AF005 | Waterhen | Oil refinery | Cold Lake in situ | A70 | Cold Lake area | 1989 | SD2 | 0.0043 | 2 300 bbl/d |

* From Reference 1

**Data not available. For computational purposes an estimate was made.

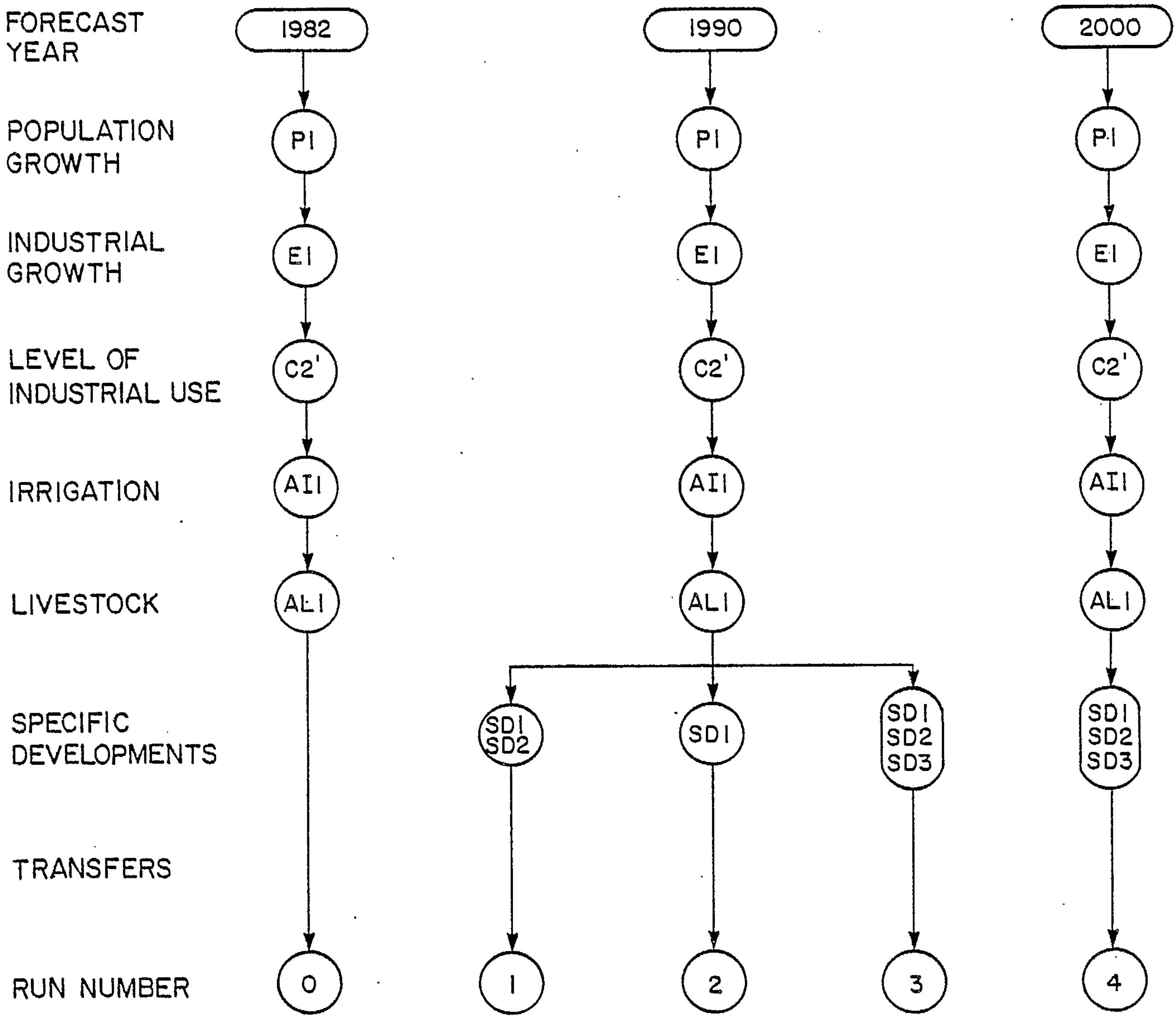
October and April. This was Run 9 and it compares directly to Run 10, except for the effect of the transfer.

(g) Two other runs were made to evaluate a "least use" and a "greatest use" scenario. These runs used all respective extremes of scenario components in order to evaluate the magnitude of total variability which can be predicted within the model. Runs 2 and 16.

(h) All of these previous variations were evaluated assuming a forecast extending to 1990. An additional run was made for 1982 (Run 0). This run was intended to serve as a base indicator of current water-related conflicts according to the water use model. Another run (Run 18) was made for a forecast year of 2000. Three runs (0, 8, 18) were used to evaluate changes in time with all growth rates and use coefficients identical. The primary difference in these runs was due to increases in population and development and the addition of specific energy-related developments in their estimated sequence.

### 6.3.2 - The Beaver River Basin

The Beaver River Basin was analyzed for five different scenarios. The particular runs made corresponded to Runs 0, 6, 8, 10 and 18 of the South Saskatchewan test case. The primary difference was the use of default industrial water use coefficients instead of the basin-specific industrial water use coefficients (developed only for the South Saskatchewan River). Figure 6.6 shows the evaluation strategy which was used for the Beaver River Basin.




LEGEND

- PI FERTILITY INCREASE AND SOME MIGRATION
- EI ECONOMIC COUNCIL OF CANADA
- C2' EXPECTED USE DEFAULT COEFFICIENTS
- AII GROWTH IN IRRIGATION - LOW (EXPECTED)
- ALI GROWTH IN LIVESTOCK POPULATION - LOW
- SDI SPECIFIC DEVELOPMENTS - PLANNED 1980-1988
- SD2 SPECIFIC DEVELOPMENTS - PLANNED 1989-1993
- SD3 SPECIFIC DEVELOPMENTS - PLANNED 1994-2000

FIG. 6.6

ALTERNATIVE TEST CASE SCENARIOS FOR THE BEAVER RIVER

ACRES

Specific energy-related specific developments in this basin are expected to have a significant impact on future water availability. Consequently the impact of these developments was evaluated in this test case. Table 6.1 lists the particular specific developments which are applicable to the Beaver River Basin.

Two issues have been addressed in this test case.

(a) The effects of three different development scenarios for a constant base year (1990) were examined. The questions addressed are identical to those discussed in point (e) of Section 6.3.1. The first scenario (Run 2) assumes that in 1990 only SD1 projects are active. The second scenario (Run 1) assumes that in 1990 SD1 and SD2 projects are on-line. The third scenario (Run 3) assumes that in 1990 SD1, SD2 and SD3 projects have been developed.

(b) The effects of general growth over time were examined. Three runs are used to evaluate the impact of growth in industrial output and population in the basin as well as specific developments. Runs 0, 2 and 4 for the respective years of 1982, 1990 and 2000 are used for this comparison.

## 6.4 - Data Requirements

Data requirements for the Water Use Forecasting Model are quite extensive, as explained previously in Section 3.

Industrial water use coefficients have been developed in Appendix B for low, expected and high default values. Basin-specific industrial water use coefficients were developed for the South Saskatchewan River Basin using data from the Prairie Provinces Water Demand Study (Reference 18). The development of these calibrated coefficients is explained later in this section.

Agricultural water use coefficients were developed as documented in Appendix A. These values are specific to the South Saskatchewan River Basin and were derived using data from Agriculture in the Saskatchewan-Nelson Basin (Reference 3), Agroclimatic Atlas of Canada (Reference 4), Technical Report No. 4 - Natural Flows (Reference 22), and Forecasting the Demand for Water (Reference 23).

Naturalized monthly flow data are used as the measure of surface water availability. The sources of the data and additional adjustments which were required are explained in the following subsection.

### 6.4.1 - Discharge Data

Naturalized monthly streamflow records were obtained from the Prairie Provinces Water Board (PPWB). These records are complete for the period 1912 to 1967 and many stations also have data available for the period 1968 to 1975. The PPWB used data extension correlation techniques to derive complete data for the 56-yr base period. The PPWB naturalized flows were obtained from historic gauge flow data through the addition of historic irrigation consumption and through adjustments for regulation. Municipal and industrial uses are historically small and, consequently, were ignored by the PPWB.

Water Supply for the Saskatchewan-Nelson Basin (Reference 40) explains in great detail the various techniques used to derive natural flow records.

The PPWB naturalized streamflows do not include the effects of existing regulation and diversions, however for the current test case these effects are relevant and must be incorporated in the hydrologic record. Fortunately, the PPWB developed adjustment flow files (K-files) which assume the 1970 level of regulation and diversions existed through the entire 1912 to 1967 period. These files were originally developed for use in a planning study and, consequently, are ideally suited to the current test case. The test case therefore assumes that the 1970 level of regulation and diversion existed throughout the 56-yr period. Additionally, the test case ignores any regulation or diversion which is more recent than 1970 or which is expected to be developed in the future.

The regulating effects of Diefenbaker reservoir were, of course, not available in 1970 and these effects have been ignored in this test case. It was anticipated that, even without this added regulation, water deficits would not be severe in the area around and below this reservoir.

Table 6.2 lists the various adjustment flow files (K-files) which were used. These files include adjustments for the following factors

- storage increments
- evaporation losses
- diversions.

It was not necessary to include all the diversion adjustments because many applied only to diversions originating and ending within a subbasin described by a nodal point in the current test case system.

TABLE 6.2

RESERVOIR AND DIVERSION ADJUSTMENTS

| K-File | Description |
|---|---|
| KC01 | St. Mary Basin in USA - Net of Diversion and Change in Storage |
| KN02 | St. Mary Reservoir Storage Increments |
| KE03 | St. Mary Reservoir Evaporation Loss |
| KN04 | Waterton Reservoir Storage Increments |
| KN15 | Bow River Basin Upstream from Calgary - Net Storage Increments |
| KN31 | Reid Lake Reservoir Storage Increments |
| KC48 | St. Mary and Milk Rivers Development - Gross Diversion from St. Mary River |
| KC51 | Eastern Irrigation District - Gross Diversion from Bow River |
| KC53 | Bow River Irrigation District - Gross Diversions from Bow River |
| KC54 | Western Irrigation District - Gross Diversions from Bow River |
| KE62 | Waterton Reservoir Evaporation Loss |

Table 6.3 lists each gauge point in the South Saskatchewan River test case and explains either where the data originated or how the data were synthesized for the entire period. The adjustment K-files which were applied to each gauge and the direction of adjustments, whether they are additive or subtractive, is also listed.

Historic gauged streamflow records from the Water Survey of Canada (WSC) were used for the Beaver River Basin as PPWB naturalized flows were not available. However, the current level of development is not expected to cause large demands on existing supplies and consequently gauge and natural flow records should be almost identical. Data for a long base period were not available and the simulation was done for only 11 years.

### 6.4.2 - Industrial Water Use Coefficients for the South Saskatchewan River Basin

The model uses national industrial water use coefficients in default of specific subbasin values. As national values are averages of all production processes in a sector, their use can result in substantial differences between actual and computed water use in a specific subbasin. Therefore, specific subbasin coefficients should be used where possible.

The base for the specific calibration of industrial coefficients for the South Saskatchewan test case is 1976 industrial water use data published in the Prairie Province Water Demand Study (Reference 18).

The 1981 water use coefficients specific to the subbasin were derived by examining the 1976 actual subbasin water use (according to Prairie Provinces Water Demand Study) with the

TABLE 6.3

ADJUSTMENTS AND SOURCES OF FLOW DATA

| Gauge* | Source | Adjustments Sign** | Adjustments K-File |
|---|---|---|---|
| 5AD007 | PPWB | - | KC01 |
| | | - | KN02 |
| | | - | KE03 |
| | | - | KN04 |
| | | - | KC48 |
| | | - | KE62 |
| 5BM004 | PPWB | - | KN15 |
| 5BM004 | PPWB | - | KN15 |
| | | - | KC51 |
| | | - | KC53 |
| | | - | KC54 |
| 5BN012 | $Q^{***} = \left[Q_{5AJ001} - Q_{5AD007} - Q_{5BM004}\right] \times \left[\frac{A_{5BN012}^{****}}{A_{5AJ001} + A_{5BN012}}\right] + Q_{5BM004}$ | - | KN15 |
| | | - | KC51 |
| | | + | KC53 |
| | | - | KC54 |
| 5CC002 | PPWB | | na |
| 5CE001 | $Q = \left[Q_{5CK004} - Q_{5CC002}\right] \times \left[\frac{A_{5CE001}}{A_{5CK004} + A_{5CH007} + A_{5CE005} + A_{5CE001}}\right] + Q_{5CC002}$ | + | KC54/2 |

Table 6.3

Adjustments and Sources of Flow Data - 2

| Gauge* | Source | Adjustments Sign** | Adjustments K-File |
|---|---|---|---|
| 5CE005 | $Q = \left[Q_{5CE001} - Q_{5CC002}\right] \times \left[\frac{A_{5CE005}}{A_{5CE001}}\right]$ | + | KC54/2 |
| 5CH007 | $Q = \left[Q_{5CE001} - Q_{5CC002}\right] \times \left[\frac{A_{5CH007}}{A_{5CE001}}\right]$ | | |
| 5CK004 | PPWB | + | KC51 |
| | | + | KC54 |
| 5AJ001 | PPWB | - | KC01 |
| | | - | KN02 |
| | | - | KE03 |
| | | - | KN04 |
| | | - | KE62 |
| | | - | KN15 |
| | | - | KC48 |
| | | - | KC51 |
| | | - | KC54 |
| 5AK001 | $Q = \left[Q_{5HB001}{*****} - Q_{5CK004} - Q_{5AJ001}\right] \times \left[\frac{A_{5AK001}}{A_{5HB001} + A_{5AK001}}\right] + Q_{5AJ001}$ | - | KC01 |
| | | - | KN02 |
| | | - | KE03 |
| | | - | KN04 |
| | | - | KE62 |
| | | - | KN15 |
| | | - | KC48 |
| | | - | KC51 |
| | | - | KC54 |

Table 6.3

Adjustments and Sources of Flow Data - 3

| Gauge* | Source | Adjustments Sign** | Adjustments K-File |
|---|---|---|---|
| 5HD039 | $Q = \left[ Q_{5HG001} - Q_{5CK004} - Q_{5AJ001} \right] \times \left[ \frac{A_{5HD039}}{A_{5HG001} + A_{5AK001} + A_{5HD039}} \right]$ | - | KN31 |
| 5HG001 | PPWB | - | KC01 |
| | | - | KN02 |
| | | - | KE03 |
| | | - | KN04 |
| | | - | KE62 |
| | | - | KN15 |
| | | - | KN31 |
| | | - | KC48 |
| 5HH001 | PPWB | - | KC01 |
| | | - | KN02 |
| | | - | KE03 |
| | | - | KN04 |
| | | - | KE62 |
| | | - | KN15 |
| | | - | KN31 |
| | | - | KC48 |

* Reference Figure 6.2 for gauge names and relative location.

** Sign indicates whether file is added to or subtracted from base file of PPWB or synthesized natural flow data.

*** Q is synthesized natural flow data for the gauge.

**** A is the local drainage area for each gauge point not the total area above that point.

*****Gauge 5HB001 is not in the test case network but PPWB data were available for it.

1976 water use computed on the basis of 1976 national average data. If the actual 1976 water use was shown to be different from the water use computed from 1976 national average data, an adjustment was made to the 1981 subbasin specific coefficient according to the following equation.

$$\text{1981 Specific Coeff} = \frac{\text{1976 Actual Water Use}}{\text{1976 Computed National Water Use}} \times \text{1981 National Water Use Coeff}$$

An example of the computation is shown in Table 6.4.

Table 6.5 shows the national industrial water use coefficients and the calibrated values for each subbasin in the South Saskatchewan River Basin.

Data were not available for calibrating the Beaver River coefficients and consequently national default values were used in this basin.

## 6.5 - Results

### 6.5.1 - General

The results of the test cases for the South Saskatchewan and Beaver rivers are discussed in the following subsections. It should be reemphasized that the purpose of the test case is to demonstrate the use of the model. A comprehensive study would require substantially more investigation particularly in the area of local groundwater use.

TABLE 6.4

EXAMPLE OF CALIBRATION - INDUSTRIAL
WATER USE COEFFICIENTS - BOW RIVER SUBBASIN

| Sector | Estimated 1976 Use (MCM) | Employment Percentage of Prairie Provinces | 1976 Value of Shipments in Prairie Provinces ($x10⁶) | 1976 Value of Shipments in Subbasin ($x10⁶) | 1976 National Average Industrial Water Use Coefficient* (MCM/$x10⁶) | Calculated 1976 Industrial Water Use (MCM) |
|---|---|---|---|---|---|---|
| Mineral Extraction | 5.845 | | | | | |
| 3 - Metal Mines | | 0.00 | 466.7 | 0.0 | 0.10859 | 0.000 |
| 4 - Fuels, Oil and Gas | | 46.79 | 5,842.0 | 2,733.5 | 0.00497 | 13.585 |
| 5 - Fuels, Coal | | 14.28 | 192.6 | 27.5 | 0.00455 | 0.125 |
| 6 - Nonmetallic Mines | | 0.62 | 640.9 | 4.0 | 0.06544 | 0.262 |
| TOTAL | | | | | | 13.972 |

Correction Factor Applied to 1981 National Coefficients: $\frac{5.843}{13.972} = 0.418$.

Industrial Water Use Coefficients

| | 1981 National Coefficient (MCM/$x10⁶) | 1981 Adjusted Coefficient Bow River Basin (MCM/$x10⁶) |
|---|---|---|
| Metal Mines | 0.07612 | 0.03185 |
| Fuels, Oil and Gas | 0.00460 | 0.00192 |
| Fuels, Coal | 0.00572 | 0.00239 |
| Nonmetallic Mines | 0.09867 | 0.04107 |

*Computed on the basis of 1976 national value of shipments and 1976 national water use. All data supplied by Statscan.

TABLE 6.5

SUBBASIN SPECIFIC INDUSTRIAL WATER USE COEFFICIENTS

| Industry | 1981 National Average Intake Coefficients (MCM/$x10⁶/yr) | | | 1981 Recirculation Factor | 1981 Average Consumption (%) | Bow River 5BH004 5BM004 5BN012 | | Oldman 5AD007 | | South Saskatchewan: Alberta 5AK001 5AJ001 | | South Saskatchewan: Saskatchewan 5HG001 5HH001 | | Red Deer 5CC002 5CK004 5CH007 5CE001 5CE005 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low | Expected | High | | | Intake Coeff. (MCM/$x10⁶/yr) | Consump. (%) | Intake Coeff. (MCM/$x10⁶/yr) | Consump. (%) | Intake Coeff. (MCM/$x10⁶/yr) | Consump. (%) | Intake Coeff. (MCM/$x10⁶/yr) | Consump. (%) | Intake Coeff. (MCM/$x10⁶/yr) | Consump. (%) |
| Agriculture | 0.00000 | 0.00000 | 0.00000 | 1.00 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 |
| Forestry, etc | 0.71500 | 0.79300 | 0.87100 | 2.59 | 75.0 | 0.79300 | 75.0 | 0.79300 | 75.0 | 0.79300 | 75.0 | 0.79300 | 75.0 | 0.79300 | 75.0 |
| Metal Mines | 0.06900 | 0.07612 | 0.08379 | 3.66 | 94.0 | 0.03185 | 89.7 | 0.21603 | 75.9 | 0.60820 | 92.1 | 0.02482 | 50.5 | 0.01385 | 97.3 |
| Fuels, Oil & Gas | 0.00411 | 0.00460 | 0.00512 | 2.62 | 77.4 | 0.00192 | 89.7 | 0.01305 | 75.9 | 0.03675 | 92.1 | 0.00150 | 50.5 | 0.00084 | 97.3 |
| Fuels, Coal | 0.00505 | 0.00572 | 0.00674 | 2.64 | 90.7 | 0.00239 | 89.7 | 0.01623 | 75.9 | 0.04570 | 92.1 | 0.00186 | 50.5 | 0.00104 | 97.3 |
| Nonmetal Mines | 0.08746 | 0.09817 | 0.11244 | 2.24 | 22.4 | 0.04107 | 89.7 | 0.27864 | 75.9 | 0.78438 | 92.1 | 0.03200 | 50.5 | 0.01787 | 97.3 |
| Food & Beverages | 0.01344 | 0.01496 | 0.01648 | 1.42 | 8.1 | 0.00960 | 21.5 | 0.03893 | 7.1 | 0.00435 | 11.0 | 0.00470 | 24.1 | 0.00168 | 6.8 |
| Tobacco | 0.00093 | 0.00109 | 0.00126 | 6.36 | 24.2 | 0.00109 | 24.2 | 0.00109 | 24.2 | 0.00109 | 24.2 | 0.00109 | 24.2 | 0.00109 | 24.2 |
| Rubber | 0.13065 | 0.14318 | 0.15750 | 1.31 | 0.8 | 0.08304 | 0.8 | 0.01432 | 0.8 | 0.02992 | 7.2 | 0.01475 | 0.8 | 0.00558 | 0.8 |
| Plastics | 0.19507 | 0.21203 | 0.23238 | 1.31 | 0.7 | 0.12298 | 0.7 | 0.02120 | 0.7 | 0.04431 | 7.2 | 0.02184 | 0.7 | 0.00827 | 0.7 |
| Leather | 0.00373 | 0.00397 | 0.00421 | 1.10 | 6.9 | 0.00397 | 6.9 | 0.00397 | 6.9 | 0.00397 | 6.9 | 0.00397 | 6.9 | 0.00397 | 6.9 |
| Textiles | 0.01226 | 0.01437 | 0.01606 | 1.71 | 5.3 | 0.01949 | 5.3 | 0.01437 | 5.3 | 0.01437 | 5.3 | 0.01437 | 5.3 | 0.01437 | 5.3 |
| Wood | 0.04052 | 0.04468 | 0.04936 | 1.48 | 2.6 | 0.00049 | 62.5 | 0.04468 | 2.6 | 0.04468 | 2.6 | 0.04468 | 2.6 | 0.04468 | 2.6 |
| Furniture | 0.00065 | 0.00072 | 0.00078 | 1.40 | 28.6 | 0.00072 | 28.6 | 0.00072 | 28.6 | 0.00072 | 28.6 | 0.00072 | 28.6 | 0.00072 | 28.6 |
| Paper, Mills | 0.25452 | 0.28385 | 0.31245 | 3.13 | 3.7 | 0.28385 | 3.7 | 0.28385 | 3.7 | 0.28385 | 3.7 | 0.28385 | 3.7 | 0.28385 | 3.7 |
| Paper, Finishing | 0.10169 | 0.11035 | 0.11900 | 3.10 | 3.6 | 0.11035 | 3.6 | 0.11035 | 3.6 | 0.11035 | 3.6 | 0.11035 | 3.6 | 0.11035 | 3.6 |
| Printing | 0.00087 | 0.00097 | 0.00109 | 12.81 | 2.9 | 0.00097 | 2.9 | 0.00097 | 2.9 | 0.00097 | 2.9 | 0.00097 | 2.9 | 0.00097 | 2.9 |
| Iron, Mills | 0.10739 | 0.11988 | 0.13236 | 2.50 | 4.2 | 0.00144 | 44.8 | 0.00156 | 25.0 | 0.11988 | 4.2 | 0.00468 | 4.2 | 0.00240 | 4.2 |
| Iron, Foundries | 0.09928 | 0.10973 | 0.12018 | 2.50 | 4.0 | 0.00132 | 44.8 | 0.00143 | 25.0 | 0.10973 | 4.0 | 0.00428 | 4.0 | 0.00219 | 4.0 |
| Other, Smelting | 0.18789 | 0.21023 | 0.23156 | 1.62 | 3.2 | 0.00252 | 44.8 | 0.00273 | 25.0 | 0.21023 | 3.2 | 0.00820 | 3.2 | 0.00420 | 3.2 |
| Other, Extruding | 0.15508 | 0.17059 | 0.18998 | 1.63 | 3.3 | 0.00205 | 44.8 | 0.00222 | 25.0 | 0.17059 | 3.3 | 0.00665 | 3.3 | 0.00341 | 3.3 |
| Metal Fabricating | 0.00355 | 0.00420 | 0.00452 | 2.22 | 3.8 | 0.00865 | 1.3 | 0.00756 | 3.8 | 0.00420 | 3.8 | 0.00756 | 3.8 | 0.00756 | 3.8 |
| Machinery | 0.00165 | 0.00183 | 0.00200 | 1.78 | 61.3 | 0.00183 | 61.3 | 0.00183 | 61.3 | 0.00183 | 61.3 | 0.00183 | 61.3 | 0.00183 | 61.3 |
| Trans. Equipment | 0.01726 | 0.01899 | 0.02040 | 1.50 | 0.4 | 0.00480 | 0.4 | 0.01899 | 0.4 | 0.01899 | 0.4 | 0.02391 | 0.4 | 0.00416 | 0.4 |
| Electric Products | 0.00588 | 0.00625 | 0.00671 | 2.72 | 2.3 | 0.00625 | 2.3 | 0.00625 | 2.3 | 0.00625 | 2.3 | 0.00625 | 2.3 | 0.00625 | 2.3 |
| Nonmetal Mineral | 0.03047 | 0.03390 | 0.03916 | 1.92 | 9.9 | 0.29188 | 58.2 | 0.04560 | 13.5 | 0.00176 | 14.7 | 0.00837 | 90.8 | 0.00420 | 53.3 |
| Petrol Refineries | 0.04620 | 0.05104 | 0.05654 | 2.14 | 5.1 | 0.01123 | 18.6 | 0.00510 | 5.1 | 0.00510 | 5.1 | 0.00510 | 5.1 | 0.00077 | 5.1 |
| Petroleum & Coal | 0.81177 | 0.89836 | 0.98134 | 2.13 | 5.1 | 0.19764 | 18.6 | 0.08984 | 5.1 | 0.08984 | 5.1 | 0.08984 | 5.1 | 0.01348 | 5.1 |
| Chemicals, Indust | 0.12063 | 0.13372 | 0.14544 | 2.20 | 6.3 | 0.36345 | 3.2 | 0.13372 | 6.3 | 0.09989 | 58.0 | 0.13372 | 6.3 | 0.13372 | 6.3 |
| Chemicals, Other | 0.19853 | 0.22153 | 0.24582 | 2.20 | 6.3 | 0.22153 | 6.3 | 0.22153 | 6.3 | 0.22153 | 6.3 | 0.22153 | 6.3 | 0.22153 | 6.3 |
| Misc. Manufacture | 0.00380 | 0.00424 | 0.00460 | 2.10 | 11.0 | 0.00424 | 11.0 | 0.00424 | 11.0 | 0.00424 | 11.0 | 0.00424 | 11.0 | 0.00424 | 11.0 |
| Construction | 0.00000 | 0.00000 | 0.00000 | 1.00 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 |
| Transportation | 0.00000 | 0.00000 | 0.00000 | 1.00 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 |
| Electric Power | 1.43936 | 1.59819 | 1.73717 | 1.00 | 1.1 | 1.59819 | 1.1 | 1.59819 | 1.1 | 1.59819 | 1.1 | 1.59819 | 1.1 | 1.59819 | 1.1 |
| Other Utilities | 0.00000 | 0.00000 | 0.00000 | 1.00 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 |
| Trade | 0.00605 | 0.00664 | 0.00728 | 1.00 | 2.2 | 0.00664 | 2.2 | 0.00664 | 2.2 | 0.00664 | 2.2 | 0.00664 | 2.2 | 0.00664 | 2.2 |
| Other | 0.00000 | 0.00000 | 0.00000 | 1.00 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 | 0.00000 | 0.0 |

In the test case major emphasis has been placed on the evaluation of consumption relative to water availability. The primary indicator of water use conflicts is the number of occurrences in the monthly record when water consumption exceeded 70 percent of the available supplies. For the purpose of further explanation these events are termed deficiencies. Much less weight is given in the evaluation to the ratio of gross intake to supply since this ratio is very dependent on the distribution of the water uses in the subbasin. The consumption data do not suffer this dependency.

Care must also be exercised in examining the absolute number of deficiencies in a subbasin. For example a very large number of deficiencies may result if streamflow at a gauge decreases to zero in the winter due to freeze-up. Other sources such as groundwater would satisfy the water requirement however for the purpose of this test case groundwater supply was set to zero since actual data were not readily available. The change in the number of deficiencies from one case to another is therefore a better indicator of the relative impact of a development scenario. Notwithstanding the above provision, any subbasin demonstrating a number of deficiencies should be examined in more depth to establish the reason behind the deficiencies. In some cases this can be done from the detailed output, in other cases more detailed data and a spatial breakdown of water users in the subbasin will be necessary.

### 6.5.2 - The South Saskatchewan River Basin

The questions outlined in Section 6.3.1 were evaluated using 19 runs of the Water Use Forecasting Model as documented in Figure 6.5. Basic data for the runs including forecast scenarios and water use coefficients are documented in the tables in Section 3.

It can be concluded generally that the factors of primary significance to future water-related conflicts in this basin are the following

- the number and magnitude of future, specific energy-related developments

- the amount of future irrigation development.

These general conclusions were, of course, expected.

Table 6.6 lists the number of months within each subbasin where the water consumption to supply ratio exceeded 70 percent. The run numbers may be referenced to Figure 6.5.

Prior to a detailed study of the questions posed in Section 6.3.1, the following general comments, particularly with respect to Run 0 (base case 1982 run), should be noted.

- Three gauges--Berry Creek (05CH007), Rosebud (05CE005) and Swift Current Creek (05HD039)--show a large number of deficiencies in the surface water supply. These are small creeks or rivers which freeze each year. Water supply for the subbasin at this time would likely come from ground-water which has been set to zero in this study due to lack of available data.

- The Oldman subbasin (Gauge 05AD007) and the Bow River subbasin near the mouth (Gauge 05BN012) each have a low number of deficiencies in 1982 (4 and 6 months respectively). These relatively low numbers of deficiencies are not expected to cause problems and, indeed, as deficiencies are noted if consumption is 70 percent of supply or greater, no problem may currently exist. These low numbers of deficiencies do indicate that these two subbasins may

TABLE 6.6

SUMMARY OF MONTHLY CONSUMPTION DEFICIENCIES - SOUTH SASKATCHEWAN RIVER TEST CASE

| Run No./ Gauge No.* | Number of Months When Consumption is Greater Than 70 Percent of Supply | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| Red Deer | | | | | | | | | | | | | | | | | | | |
| 05CC002 | 0 | 0 | 16 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| 05CE001 | 0 | 0 | 172 | 0 | 0 | 0 | 74 | 0 | 0 | 1 | 168 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 171 |
| 05CH007** | 233 | 264 | 272 | 264 | 264 | 267 | 264 | 264 | 264 | 264 | 264 | 271 | 264 | 264 | 264 | 264 | 233 | 264 | 264 |
| 05CE005** | 143 | 144 | 155 | 144 | 154 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 154 | 154 | 144 | 144 | 154 | 144 | 145 |
| 05CK004 | 0 | 0 | 147 | 0 | 0 | 0 | 89 | 0 | 0 | 0 | 142 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 144 |
| Bow | | | | | | | | | | | | | | | | | | | |
| 05BH004 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 05BM004 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 05BN012 | 6 | 6 | 15 | 6 | 6 | 6 | 6 | 3 | 6 | 6 | 6 | 11 | 6 | 6 | 6 | 6 | 6 | 6 | 7 |
| Oldman | | | | | | | | | | | | | | | | | | | |
| 05AD007 | 4 | 8 | 19 | 7 | 6 | 9 | 7 | 7 | 7 | 8 | 8 | 18 | 7 | 7 | 7 | 8 | 6 | 8 | 9 |
| South Saskatchewan | | | | | | | | | | | | | | | | | | | |
| 05AJ001 | 36 | 42 | 76 | 42 | 42 | 53 | 42 | 33 | 42 | 44 | 44 | 75 | 42 | 42 | 42 | 42 | 41 | 42 | 43 |
| 05AK001 | 25 | 29 | 58 | 29 | 29 | 36 | 29 | 23 | 29 | 31 | 31 | 54 | 29 | 29 | 29 | 29 | 29 | 29 | 29 |
| 05HD039** | 228 | 232 | 273 | 232 | 232 | 260 | 232 | 232 | 232 | 232 | 232 | 272 | 232 | 232 | 232 | 232 | 232 | 232 | 260 |
| 05HG001 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 05HH001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Number of Deficiencies*** | 71 | 85 | 506 | 84 | 83 | 105 | 262 | 66 | 84 | 90 | 415 | 159 | 85 | 84 | 84 | 85 | 82 | 85 | 420 |

* Reference Figure 6.3 for gauge name and relative location.

** The failure rate for these gauges reflects low winter flows. Gauge 05CH007 had 207 months, with no natural stream supply. Gauge 05CE005 had had 135 months with no natural stream supply. Gauge 05HD039 had 111 months with no natural stream supply. Many other months would be expected to have low flows as well. In fact, the demand is likely satisfied from groundwater, a component which is currently not included in the water management model.

***The totals exclude Gauge 05CH007, 05CE005 and 05HD039 because of the problems discussed above.

well experience problems in the future if planning of water using problems is not carefully controlled.

- The South Saskatchewan River near Medicine Hat (Gauge 05AJ001) and also at Highway 41 (Gauge 05AK001) recorded 36 and 25 deficiency months in the 55 years of record respectively. This frequency of occurrence indicates that significant problems are likely occurring periodically. Although on-site confirmation has not been undertaken for this study, it is understood that this is consistent with what is actually occurring in the subbasin.

- No problems occur with the South Saskatchewan River at Saskatoon (Gauge 05HG001) or at St. Louis (Gauge 05HH001).

The results of the individual issues originally presented in Section 6.3.1 (a) through (h) are discussed below.

(a) Population Growth

The following runs represent alternative scenarios of population growth in order of increasing growth rate and as noted in Figure 6.5. Actual data are documented in Tables 3.8(a) to (d).

Run 8 - Scenario 1*
Run 15 - Scenario 3*
Run 1 - Scenario 2*
Run 17 - Scenario 4*

*For detailed description see Tables 3.8(a) to (d).

In comparing the results of these runs among themselves and against the base 1982 case (Run 0), it is evident that differences in the population growth scenario do not affect water use deficiencies.

(b) Economic Growth

The following runs represent alternative scenarios of industrial growth as predicted by three alternative forecasts. Actual data are documented in Tables 3.9(a) to (c).

Run 8 - Based on Economic Council of Canada
Run 3 - Based on University of Toronto National Forecast
Run 14 - Based on University of Toronto Western Forecast.

Again, in comparing the results among themselves and against the 1982 base case, (Run 0), it is evident that any differences in the economic forecasts do not affect the deficiencies in water use.

(c) Industrial Water Use Coefficients

The following runs represent alternative scenarios with different industrial water use coefficients. The actual coefficients are documented in Table 3.3.

Run 4 - Low coefficients based on national averages
Run 13 - Expected coefficients based on national averages
Run 12 - High coefficients based on national averages
Run 8 - Calibrated coefficients based on subbasin specific data.

Comparison of the results in Table 6.6 shows that variability in the coefficients does not affect the number of deficient months.

(d) Agricultural Growth

Three annual agricultural growth rates have been projected as defined in the following runs.

Run 8 - Low growth rate (0.5 percent/yr Alberta, 1.0 percent/yr Saskatchewan for irrigation)
Run 5 - Medium growth rate (1.3 percent/yr Alberta, 2.5 percent/yr Saskatchewan for irrigation)
Run 11 - High growth rate (2.65 percent/yr Alberta, 5.0 percent/yr Saskatchewan for irrigation)

Currently there are no large-scale irrigation projects under construction in the basin or in the final design stages. Because the required lead time for such projects is long, the low growth rate is to be expected at least to the forecast year of 1990.

The impact of agricultural development is particularly evident in the Oldman Basin (Gauge 05AD007 at Lethbridge) and at the South Saskatchewan River Basin (Gauges 05AJ001 at Medicine Hat and 05AK001 at Highway 41).

In each case the additional agricultural development exacerbates water use conflicts which already exist.

In the case of the Oldman Basin this problem does not appear to be severe. Although the number of deficiencies increases from 4 to 18 in comparing the base case (Run 0) with the high growth rate case (Run 11), it is expected that this level of deficiency could be handled by rationing. It is also pointed out once again that the 70 percent level of consumption to supply ratio chosen as the deficiency level is somewhat arbitrary. What the analysis does emphasize is a need for careful water resource planning in the Oldman Basin in the near future.

Note that the increase in agricultural development causes no additional stress in the Red Deer Basin since irrigated agriculture is minimal. In the Bow Basin as indicated by Gauge 05BN012 (near the mouth) a significant increase in stress would be felt if the highest growth rate for agriculture is developed.

Examining the "Total" data in Table 6.6 shows an increase in the number of deficiencies from the 1982 condition (Run 0) to the 1990 condition (Run 8) at an expected (low) growth rate of 71 to 84 or 18 percent. It should be noted however that Run 8 includes "expected" growths in other sectors as well as special developments. Comparing deficiencies at higher agricultural growth rates shows a 48 percent increase in the number of deficiencies resulting from medium growth (Run 5) and 224 percent from high growth (Run 11).

(e) Specific Developments

Three levels of development in energy-related projects were examined as part of the test case

Run 8 - Specific Developments planned for 1980 to 1988 (essentially committed projects - [called SD1 projects])

Run 6 - Specific Developments planned for 1989 to 1993 (called SD2 projects) plus all SD1 projects

Run 10 - Specific Developments planned for 1994 to 2000 (called SD3 projects) plus all SD1 and SD2 projects.

The specific details of these projects are listed in Table 6.1. Note that for the purpose of this study it is assumed that these three groups of projects represent alternative development levels to the year 1990.

The impact of energy-related developments is particularly evident in the Red Deer Basin. Comparing Run 0 (1982) with Run 8 (1990 - level SD1) and examining Table 6.1 shows that the addition of the Sheerness thermal power plant above Gauge 05CK004 (near Blindloss) should not cause additional stress. No increase in the deficiency rate is noted. Adding the Sheerness and Rose Lynn coal mines, however, to the water demands from Berry Creek would cause a significant increase in the number of deficiencies. It is expected, however, that these projects have secured alternative sources of water.

Adding the projects of SD2 and SD3 (as listed in Table 6.1) to the upper Red Deer Basin (Gauge 05CC002 at Red Deer and Gauge 05CE001 at Drumheller) causes increased and, no doubt, unacceptable stress to the water resource. This is recognized and the problem will be substantially alleviated by the new Dickson storage dam which has been constructed upstream from the city of Red Deer. This dam was planned for water supply and low flow augmentation.

The specific developments planned for the Bow River Basin including two thermal power stations, a coal mine and an oil refinery do not appear to cause additional water use conflicts.

In the South Saskatchewan subbasin, as represented by Gauge 05AJ001, the addition of the Medicine Hat methanol plant (SD1) causes no significant increase in the number of deficiencies. Similarly, the thermal power plant planned for New Bridgeford as part of SD3 does not cause a significant increase in water stress. The impact of agricultural developments in these subbasins far outweighs the planned energy-related developments.

(f) Transfer

(i) Transfers Internal to a Specific Basin - As discussed in Section 6.3.1, a transfer from the Red Deer River at Drumheller (Gauge 05CE001) to the Bow River below Bassano dam (Gauge 05BM004) was studied in an attempt to alleviate the shortage problems on the lower Bow River and the upper South Saskatchewan. The diversion amounts were 20 $m^3/s$ for June, July and August and 5 $m^3/s$ in May and September. Run 8 was used as the base case (without transfer) and Run 7 as the test case (with transfer).

The results are clear. Water use deficiencies were reduced significantly at all gauges on the lower Bow (05BN012) and South Saskatchewan (05AJ001 and 05AK001) with no increase in the number of deficiencies on the Red Deer.

(ii) Transfers from External Sources - A transfer from the North Saskatchewan River to the Red Deer Basin at Red Deer (Gauge 05CC002) was tested to see if the deficiencies resulting from the high level of industrial development could be alleviated. Run 10 was used as the base case (without transfer) and Run 9 was used on the test case with transfer. Transfer rates were 10 $m^3/s$ from November to March and 5 $m^3/s$ in October and April. The results show a dramatic reduction in the number of deficiencies from 168 to 1. It is noted, however, that no consideration has been given to increases in deficiencies (if they exist) on the North Saskatchewan.

In order to evaluate this, the model must be run for the entire Saskatchewan River system.

(g) "Least Use" and "Greatest Use" Scenarios

Runs 16 and 2 were used to evaluate the "least use" and "greatest use" conditions respectively. The "least use" scenario has results which are quite similar to the expected use, while the "greatest use" scenario has a much larger deficiency rate. This large number of deficiencies is due primarily to a high agricultural growth forecast and the inclusion of SD1, SD2 and SD3 projects. A significant proportion of the total deficiencies occurs in the Red Deer Basin, however, much of the forecasted shortage may be alleviated by the new storage provided on the Red Deer above the city of Red Deer.

(h) Development Over Time

The analysis conducted above examines water use at the 1990 forecast year. Even in studying the specific energy-related developments which are spread over the period 1982 to 2003, a 1990 forecast has been used for other factors such as population, industrial and agricultural growth. Runs 0, 8 and 18 representing forecast years of 1982, 1990 and 2000 respectively may be examined to compare the "expected" increase in water use conflicts over time. Primary areas of concern (as have already been noted) are the high level of energy-related development in the Red Deer Basin causing a substantial increase in deficiencies from the year 1990 (Run 8) to the year 2000 (Run 18).

(i) Summary

The following points summarize the key findings of the investigation.

- Without regulation on the Red Deer River, severe water shortage problems would occur after 1990 if all energy-related projects proceed.
- Increased agricultural development will put increasing stress on the Oldman and lower Bow rivers. Careful planning of future water resource developments in these areas is required.
- Agricultural development on the upper South Saskatchewan near Medicine Hat and Highway 41 will exacerbate water shortage problems which now exist. Again, careful planning is required.

### 6.5.3 - The Beaver River Basin

The test case for the Beaver River involved five runs which looked at specific energy developments and general growth in the basin over time. The run strategy is shown in Figure 6.6 and the results are presented in Table 6.7. Analysis was conducted on 11 years (132 months) of available record.

Examining the 1982 base condition, corresponding to Run 0 in Table 6.7, shows that only the river near Goodridge (Gauge 06AA001) is currently under stress. A more detailed study of the output shows that the majority of monthly deficiencies occur during dry periods in the late fall and during the winter when low flows occur.

The balance of the runs addresses specific questions.

(a) Specific Development

The following runs addressed the questions of the impact of specific energy developments.

Run 2 - Special Developments planned between 1982 and 1988 (SD1)--includes Esso Cold Lake project above Gauge 06AD006.

Run 1 - Special Developments planned between 1989 and 1993 (SD2) plus SD1 projects--includes additions to the Esso Cold Lake Project and a refinery on the Waterhen River (Gauge 06AF005).

Run 3 - Special Developments planned between 1994 and 2003 (SD3) plus SD1 and SD2 projects--includes the BP Canada project on the Sand River (Gauge 06AB001).

Clearly, the Esso Cold Lake project will have a significant impact on water availability on the Beaver River. With this project added deficiencies would occur virtually every month at the Cold Lake reserve (Gauge

TABLE 6.7

SUMMARY OF MONTHLY CONSUMPTION DEFICIENCIES - BEAVER RIVER TEST CASE

| Run No./ Gauge No.* | Number of Months Where Consumption is Greater Than 70 Percent of Supply | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 |
| 06AA001 | 24 | 24 | 24 | 24 | 52 |
| 06AB001 | 0 | 0 | 0 | 101 | 101 |
| 06AD006 | 0 | 121 | 117 | 127 | 127 |
| 06AF005 | 0 | 0 | 0 | 0 | 0 |
| 06AG001 | 2 | 12 | 12 | 12 | 28 |
| Total Number of Deficiencies | 26 | 157 | 153 | 264 | 308 |

*Reference Figure 6.4 for gauge name and relative location.

06AD006). A significant increase in deficiencies is also noted at the downstream gauge (06AG001). In designing the project, an alternative water source other than the Beaver River was undoubtedly planned.

The addition of the SD2 projects causes no additional increase in stress to the Beaver at Gauge 06AB001 beyond that caused by the SD1 projects. This indicates that the two SD2 projects could be constructed without causing water use conflicts. More, detailed study is, however, required.

Finally, the addition of the SD3 project on the Sand River (Gauge 06AB001) as seen by comparing Run 3 with Run 2 causes unacceptable stress on the river. Alternative water sources will obviously be required.

(b) Development Over Time

Runs 0, 2 and 4 can be compared to study the expected development of the Beaver for 1982, 1990 and the year 2000 respectively. It is clear that the specific energy developments dominate the analysis and that alternative water sources will be required for the major projects.

## 6.6 - Comments on the Model

The test cases on the South Saskatchewan and Beaver rivers were intended to demonstrate the application of the model rather than be a definitive water resource study. These test cases have shown the need for both more detailed data related to groundwater, for more accurate representation of irrigated agriculture and the need to represent storage in some reasonable fashion. These will be high priorities for the ongoing development of the model.

Notwithstanding these requirements, the test cases have shown the model in its current form to be effective in

- establishing the factors which have significant impacts on water use and the relative importance of each

- identifying subbasins which are having problems or which may potentially have problems as a result of future development

- evaluating, in a preliminary way, various alternatives for alleviating the water stress.

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# APPENDIX A

# AGRICULTURAL WATER USE COEFFICIENTS

## APPENDIX A

## AGRICULTURAL WATER USE COEFFICIENTS

This appendix describes the derivation of the water use rates for Saskatchewan and Alberta used in the initial test runs of the model. It is intended to demonstrate the process required to establish realistic subbasin-specific use rates in the absence of an agricultural submodel. Section A1 presents the basic approach relating the intake requirements and consumptive use percentage (i.e., the program input) to crop consumptive use and efficiency. Section A2 reviews the relevant information from the available reports and articles and presents the selected water use rates.

### A1 - COMPONENTS OF IRRIGATION WATER USE

The water intake into a project or area (PIN) consists of two components: the volume to satisfy the crop requirements (CR) and the amounts in excess of these requirements (EXCESS). The crop water requirements depend mainly on climatological conditions and crop characteristics. This component, therefore, varies regionally and from year to year. The second component, the diverted amounts in excess of the requirements, is usually expressed implicitly by means of the project or intake efficiency (Ep), defined by

$$Ep = \frac{CR}{PIN} = \frac{CR}{CR + EXCESS} \qquad A.1$$

## A1.1 - Crop Requirements

The crop water requirement is the requirement for water to satisfy crop evapotranspiration in excess of water which can be supplied naturally, that is, the difference between the evapotranspiration and the sums of the effective rainfall and the available soil moisture at the beginning of the season. The evapotranspiration rate depends on climatic factors such as net incoming radiation, temperature, humidity and wind and on crop characteristics. Standard methods have been developed to calculate crop requirements, and these will be used when an agricultural submodel is prepared for addition to the core model.

Because of its dependence on climatological factors, the crop water requirement shows a distinct regional pattern which is clearly illustrated by the seasonal moisture deficit map of Canada (Agroclimatic Atlas of Canada, Ref. 4). The average deficit, which is a good indicator of the crop irrigation requirements, ranges from less than 100 mm to 400 mm. This means that the need for irrigation varies from incidental supplementary supplies to conditions under which crop production is not feasible or very restricted without irrigation. Besides regional variations, the crop water requirement also shows significant year-to-year variations, mainly caused by fluctuations in rainfall. These fluctuations are taken into account by selecting a level of probability for the annual hydrology to be used in computing water requirements. For irrigation project design, a 1-in-5 dry year is normally adopted to estimate crop requirements.

Regional variation and yearly fluctuations are illustrated in the tables of Section A2 of this appendix.

## A1.2 - Efficiency

Efficiency depends largely on factors which are controllable, such as irrigation facilities, methods of application and water operations and can be improved by project rehabilitation and good management. Achievement of high efficiency levels is typically given strong emphasis in planning studies. Several levels of efficiency are recognized such as field, distribution and farm efficiency. However, for planning studies such as this, only the combination of these efficiencies at a project level need be considered.

The project efficiency (Equation A.1) relates the project intake to the crop requirements. Not all the water diverted in excess of the crop requirements is lost. A part of it returns to the rivers in the form of return flows (RF) and can be reused downstream from the project. In order to account for these return flows, the concept of effective efficiency (Ee) has been introduced (Agriculture in the Saskatchewan-Nelson Basin, Ref. 3).

$$Ee = \frac{CR}{PIN - RF} \qquad A.2$$

The model developed in this study uses that part of the intake that is not recovered by return flow as consumptive percentage (CP). This percentage can be derived by combining Equations A.1 and A.2.

$$CP = \frac{PIN - RF}{PIN} = \frac{CR/Ee}{CR/Ep} = \frac{Ep}{Ee} \qquad A.3$$

It should be noted that data on effective efficiencies are seldom published. It will therefore often be necessary for the user to obtain measured data on project intake (PIN) and return flows (RF) to estimate the consumptive percentage (CP). Lacking these data, assumptions on Ep and Ee must then be made.

## A2 - SELECTION OF WATER USE FOR TEST CASE

This discussion is presented as an example of the approach to be taken in determining water use rates for irrigation. The project intake requirements for the test case have been selected on the basis of a review of the following reports and articles.

- Technical Report No. 4 - Natural Flows (in the Saskatchewan-Nelson Basin) (Ref. 22).
- Agriculture in the Saskatchewan-Nelson Basin (incomplete draft) (Ref. 3).
- Water Demands and Water Use Efficiencies in the Oldman River Basin (Ref. 21).

The development of estimates based on each of the three reports is outlined in the following subsections.

### A2.1 - Natural Flows in the Saskatchewan-Nelson Basin

This study estimates the net water intake for irrigation, which is the gross intake minus return flow by means of a regression equation derived for the eastern irrigation district based on data over the period 1951 to 1968.

$$\log U = C1 - C2 \log P_s - C3 \log P_{sp} \qquad \text{A.4}$$

where

C1, C2, C3: constants

U = net irrigation intake

$P_s$ = summer precipitation index

$P_{sp}$ = spring precipitation index.

This approach assumes that in this period irrigation practices and cropping patterns did not change significantly. This is in contradiction with the Agricultural Sub-Committee (Agriculture in the Saskatchewan-Nelson Basin, Ref. 3) which reports a sharp drop in irrigation water use in the early 60's probably due to technological changes.

This equation was then applied to estimate the net irrigation water use of the entire Saskatchewan-Nelson Basin. Differences in cropping patterns, project efficiency and evapotranspiration rates are neglected since rainfall is the only variable in the equation. Although it is expected that rainfall is the dominant climatic factor that causes regional differences in crop water requirements, some variation in cropping patterns and efficiencies between districts is to be expected.

Since rainfall is the dominant climatic factor, this equation can be used to compare crop water requirements of similar cropping patterns. Table A.1 shows the net irrigation intakes in cubic metres per hectare per season for 14 irrigation districts based on the 1-in-4 dry year hydrology. The prorating factors of Table A.2 were then used to distribute the annual totals to monthly amounts. The relative intake, which is the intake per unit area of a district compared with the intake per unit area at Lethbridge, is shown in Table A.1, shows a distinct regional pattern caused largely by differences in rainfall.

While this methodology presents a reasonable approach to determining project intakes, it does not discuss the consumptive percentage, return flows or effective efficiency.

TABLE A.1

NET IRRIGATION INTAKE IN A 1-IN-4 DRY YEAR COMPUTED BY EQUATION 1

| Irrigation District | Net Intake ($ft^3/s/yr$) | Irrigated Area (acres) | Unit Intake ($m^3/ha$) | Relative Intake* |
|---|---|---|---|---|
| Aetna | 4.3 | 2 500 | 3 795 | 0.71 |
| Leavit | 7.9 | 4 500 | 3 874 | 0.73 |
| Mountain View | 4.9 | 2 800 | 3 862 | 0.72 |
| United | 33.0 | 16 700 | 4 360 | 0.82 |
| Magrath | 18.4 | 8 000 | 5 075 | 0.95 |
| Raymond | 43.9 | 19 000 | 5 098 | 0.95 |
| Lethbridge N | 167.6 | 70 000 | 5 264 | 0.99** |
| Bow River | 250.6 | 78 100 | 7 080 | 1.33 |
| Eastern | 624.4 | 200 100 | 6 886 | 1.29 |
| Lethbridge SE | 220.8 | 90 400 | 5 390 | 1.01** |
| Ross Creek | 2.9 | 900 | 7 110 | 1.33 |
| St. Mary and Milk Rivers | 265.0 | 85 400 | 6 847 | 1.28 |
| Taber | 112.8 | 42 000 | 5 898 | 1.10 |
| Western | 64.5 | 25 000 | 5 693 | 1.07 |

* Unit intake rate divided by the average unit rate of the two Lethbridge districts.

**Average of Lethbridge N and Lethbridge SE equals 1.00.

TABLE A.2

PRORATING FACTORS FOR MONTHLY USES (REF. 3)

| | Percent of Annual Total | |
|---|---|---|
| | Bow River Irrigation District | All Other Districts |
| May | 5 | 10 |
| June | 10 | 25 |
| July | 15 | 25 |
| August | 30 | 20 |
| September | 30 | 10 |
| October | 10 | 10 |

## A2.2 - Agriculture in the Saskatchewan-Nelson River Study

This report discusses provincial water use studies, details of which were not available at the time of writing this appendix. The draft report used for this investigation did not have a complete set of tables, with only data on the Red Deer and Bow River subbasins complete.

This report presents project intake and net intake (project intake - return flows) as well as project and effective efficiencies in 1961, 1971, 1976 and 1978 for each subbasin. With this information, project intakes and crop water requirements have been calculated and are presented in Table A.3. The rates show a significant change between years. Since project efficiencies are decreasing slightly, this water use decrease can only be attributed to changes in cropping patterns or differences in hydrology. Indeed, an examination of the hydrologic record for these 4 years shows that rainfall variations are sufficient to explain the differences in crop water requirements.

Data on evapotranspiration are presented in the report only for Saskatchewan. These data have been used as a guide in determining the proportion of project intake distributed to each crop type as discussed further in Section A2.4

| | |
|---|---|
| - wheat,oats, barley | 4 500 $m^3$/ha |
| - hay, forage, alfalfa | 6 130 $m^3$/ha |
| - oil seed crops | 3 990 $m^3$/ha |
| - speciality crops | 4 240 $m^3$/ha. |

Table A.4 shows the best efficiencies achieved in the sub-basins in the four seasons studied and these values have been selected for the test case as representative of present

TABLE A.3

SEASONAL IRRIGATION WATER USE IN RED DEER AND BOW RIVER SUBBASINS

| | Subbasin | Crop Water Requirements* ($m^3$/ha) | Net Irrigation Intake ($m^3$/ha) | Gross Irrigation Intake ($m^3$/ha) | Project Efficiency |
|---|---|---|---|---|---|
| 1961 | RD | 4 519 | 8 932 | 10 836 | 0.417 |
| | BR | 4 610 | 9 136 | 12 037 | 0.383 |
| 1971 | RD | 3 615 | 7 248 | 9 719 | 0.372 |
| | BR | 3 998 | 7 222 | 11 200 | 0.357 |
| 1976 | RD | 2 985 | 6 265 | 8 480 | 0.352 |
| | BR | 3 620 | 5 606 | 9 282 | 0.390 |
| 1978 | RD | 1 982 | 4 172 | 5 846 | 0.339 |
| | BR | 2 285 | 3 715 | 6 400 | 0.357 |

*Calculated by means of reported efficiencies.

TABLE A.4

EFFICIENCIES

| Subbasin | Ep | Ee | CP |
|---|---|---|---|
| Red Deer | 0.417 | 0.522 | 0.80 |
| Bow River | 0.390 | 0.586 | 0.67 |
| Oldman | 0.549 | 0.685 | 0.80 |
| South Saskatchewan | 0.560 | 0.682 | 0.82 |

conditions. The project efficiencies of the Oldman River and South Saskatchewan subbasin are unusually high, however, the report does not provide reasons why this occurs.

### A2.3 - Water Demands and Water Use Efficiencies in the Oldman Basin

Maasland and Heywood (Ref. 21) have calculated crop water requirements for typical cropping patterns in Lethbridge, Medicine Hat and Cardston. As can be seen in Table A.5(a), the requirements vary considerably from year to year. In a 1-in- 4 dry year the requirements are about 20 percent higher than in a year with average rainfall. Table A.5(b) presents the cropping patterns for the three areas which are shown to be significantly different--one to the other. As a result of these cropping pattern differences, the crop criteria requirements of Table A.5(a) include the effect of both climatic and cropping pattern variations, as well as possible differences in irrigation practice.

The study presents the evapotranspiration of the individual crops and the rainfall distribution at Lethbridge. With this information the water requirements of the individual crops in a 1-in-4 dry year have been calculated and the results are given in Table A.6.

These data have then been used to calculate the crop requirements of a cropping pattern of 60 percent forages and 40 percent grains at Lethbridge. The crop requirements of this pattern are now directly comparable with those at the two other stations and for a 1-in-4 dry year are

- Lethbridge 3 600 $m^3$/ha
- Medicine Hat 4 420 $m^3$/ha
- Cardston 2 540 $m^3$/ha.

TABLE A.5(a)

CROP WATER REQUIREMENTS OF TYPICAL CROPPING PATTERNS FOR SPECIFIC RAINFALL FREQUENCIES

| | 1 in 10 Dry ($m^3$/ha/yr) | 1 in 4 Dry ($m^3$/ha/yr) | Median ($m^3$/ha/yr) |
|---|---|---|---|
| Lethbridge | 3 560 | 3 050 | 1 540 |
| Medicine Hat | 4 725 | 4 420 | 3 890 |
| Cardston | 3 100 | 2 540 | 2 032 |

TABLE A.5(b)

CROPPING PATTERNS FOR THE THREE AREAS ANALYZED

| | Grain Crops (percent) | Forages Crops (percent) | Speciality Crops (percent) |
|---|---|---|---|
| Lethbridge | 57 | 31 | 12 |
| Medicine Hat | 40 | 58 | 2 |
| Cardston | 40 | 60 | - |

TABLE A.6

CALCULATION OF CROP REQUIREMENTS
IN A 1-IN-4 DRY YEAR AT LETHBRIDGE

| Crop | Evapotranspiration ($m^3$/ha/yr) | Soil Moisture of Beginning of the Season* ($m^3$/ha/yr) | Rainfall ($m^3$/ha/yr) | Crop Requirements ($m^3$/ha/yr) |
|---|---|---|---|---|
| Alfalfa | 6 980 | 760 | 2 160 | 4 060 |
| Wheat | 5 460 | 760 | 1 780 | 2 920 |
| Sugar beet | 5 840 | 760 | 2 280 | 2 800 |

*Amount of water stored in soil during fall and winter.

These demands show a similar regional distribution to that obtained using Equation A.4 of Appendix A2.1, which was devised by a regression analysis using data for the eastern irrigation district.

Maasland and Heywood also summarize the irrigation efficiencies for the Bow River irrigation district for the period 1958 to 1968 as follows

| | |
|---|---|
| - water conveyance efficiency | 65 percent |
| - farm irrigation efficiency | 58 percent |
| - project efficiency | 38 percent. |

This project efficiency is consistent with the values presented in Table A.4.

This Oldman Basin report does not discuss return flows or consumptive percentage.

## A2.4 - Selection of Values for Test Case Runs

From the data presented in the various reports presented in Sections A2.1 to A2.3, project intake and the consumptive percentage for each crop for the subbasins in the test case were established as follows.

### Project Intake

(a) Since the most complete information was available for the Lethbridge irrigation district from the work of Maasland and Heywood, it was used as a reference area for the calculations. Crop water requirements as documented in Table A.6 were adopted. The crop water requirements for oil seed and specialty crops (not covered in the Maasland and Heywood report) were estimated from the relationship of their evapotranspiration demands to the demands of grains and forages as documented in the Saskatchewan-Nelson River Basin study.

The selected basic crop water requirements for Lethbridge are therefore as follows

| | |
|---|---|
| - forages | 4 060 $m^3$/ha |
| - grains | 2 920 $m^3$/ha |
| - sugar beets | 2 800 $m^3$/ha |
| - oil seeds | 2 200 $m^3$/ha |
| - specialty crops | 2 600 $m^3$/ha. |

(b) The crop water requirements for other irrigation districts were then determined by multiplying those requirements developed for Lethbridge by regional adjustment factors documented as relative intake in Table A.1

(c) The project intake was computed from Equation A.1 by dividing the crop water requirements by the project efficiency for the subbasin, as documented in Table A.4.

(d) In many cases, the model subbasin contains more than one irrigation district. The subbasin project intakes were then determined as an average of those irrigation districts in the subbasin weighted on the basis of size. In cases where a subbasin does not contain an irrigation district, a representative district in close proximity was used.

## Consumptive Percentage

The consumptive percentage data, as determined in the Saskatchewan-Nelson Basin Board report and documented in Table A.4, were adopted.

The final selected figures for project intake and consumptive percentage for the various subbasins in the test case are listed in Table A.7.

TABLE A.7

CONSUMPTIVE PERCENTAGE AND INTAKE PER SUBBASIN

| | | Project Intakes ($m^3$/ha/yr) | | | | |
|---|---|---|---|---|---|---|
| Subbasin | Consumption (percentage) | Grains | Forages | Sugar Beets | Oil Seeds | Specialty |
| 05AD007 | 80 | 4 990 | 6 940 | 4 790 | 3 760 | 4 450 |
| 05AJ001 | 80 | 6 750 | 9 380 | 6 470 | 5 080 | 6 000 |
| 05AK001 | 80 | 6 770 | 9 420 | 6 500 | 5 100 | 6 030 |
| 05BH004 | 80 | 7 885 | 10 965 | 7 560 | 5 940 | 4 320 |
| 05BM004 | 80 | 7 885 | 10 965 | 7 560 | 5 940 | 4 320 |
| 05BN012 | 80 | 6 750 | 9 380 | 6 470 | 5 080 | 6 000 |
| 05CC002 | 80 | 7 885 | 10 965 | 7 560 | 5 940 | 4 320 |
| 05CE001 | 80 | 7 500 | 10 430 | 7 200 | 5 650 | 6 680 |
| 05CE005 | 80 | 7 500 | 10 430 | 7 200 | 5 650 | 6 680 |
| 05CH007 | 80 | 9 020 | 12 550 | 8 650 | 6 800 | 8 300 |
| 05CK004 | 80 | 9 020 | 12 550 | 8 650 | 6 800 | 8 300 |
| 05HD039 | 80 | 6 770 | 9 420 | 6 500 | 5 100 | 6 030 |
| 05HG001 | 80 | 6 770 | 9 420 | 6 500 | 5 100 | 6 030 |
| 05HH001 | 80 | 6 770 | 9 420 | 6 500 | 5 100 | 6 030 |

# APPENDIX B

# INDUSTRIAL WATER USE COEFFICIENTS

## APPENDIX B

## INDUSTRIAL WATER USE COEFFICIENTS

Industrial water use coefficients relate water use in cubic metres by each industry to the value of output (value of shipments) by that sector. The commonly reported components of water use are

- gross use--the total volume of water required by the process

- intake--that part of the gross use which is supplied from external sources

- consumption--that part of gross use which is consumed by the process and not returned to the water source.

Two coefficients commonly used in the description of water use are

- the recirculation factor which is the proportion of gross use which is made up by intake of water from external sources

  i.e., $\text{Recirculation Factor} = \frac{\text{Gross Use}}{\text{Intake}}$

- the consumption factor which is the ratio of water consumed by the process to the intake requirement.

  i.e., $\text{Consumption Factor} = \frac{\text{Consumption}}{\text{Intake}}$

Variables required by the model to express water use are the intake in cubic metres per 1981 dollar and the consumption factor. From this information, the model computes total intake volume and consumption volume.

In developing water use coefficients for the test case, data for gross use, intake and consumption in gallons were available by industrial sector for 1971, 1972 and 1976. These were established by the Inland Waters Directorate.

The data for 1971 were suspected of being less reliable and therefore were given less weight in the analysis.

From these 3 years of data it was necessary to estimate 1981 water use for each industrial sector. In doing so, a number of factors were considered.

- The primary cause of change in total water use was the real growth of the sector between the years when data were available and 1981.

- During the intervening period, some technology change has undoubtedly taken place as a result of environmental pressures. These changes generally involve increased recirculation with a resulting overall drop in intake requirement. It is not possible to estimate the overall impact of these changes until 1981 actual water use data become available.

The change in water use relating to real growth was estimated by plotting the real growth output of each industrial sector as a function of time. The growth factor from the appropriate year to 1981 was then used to determine the 1981 water use.

The changes in recirculation from the mid-1970's to 1981 are more difficult to estimate and are impossible to demonstrate given the mid-1970's water use data. In general, it is evident that recirculation improvements are taking place in the following sectors:

- food and beverage
- textiles
- transportation
- metal mines
- pulp and paper
- iron and steel.

These factors of real growth and technological change have been taken into consideration to develop the water use coefficients presented in Table B.1. A range for the coefficients is presented reflecting a measure of the error of the estimate. This range is applicable at the provincial level but will be greater when considering small numbers of plants such as typically occurs at the subbasin level.

The 1981 value of output (shipment) by industrial sector was developed from the Statscan reports of the national output for 1980 escalated by the real increase in national output (GDP) from 1980 to 1981. These escalated amounts are also presented in Table B.1.

Finally, the water intake by industrial sector expressed in million dollars per thousand cubic meters is also documented in Table B.1 with low, medium and high values listed. Consumption is determined from the consumption factor documented in the same table.

TABLE B.1

INDUSTRIAL WATER USE (1981)

| | Industry | Gross Use | | | Intake (gal x $10^9$) | | | Recirculation Factor | Median Consumption (gals x $10^9$) | Consumption Factor (percent) | 1981 Value of Shipments ($ x $10^6$) | Intake ($m^3$ x $10^6$/$ x $10^6$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Low | Med | High | | | | | Low | Med | High |
| 1. | Agriculture | 750 | 808 | 870 | 750 | 808 | 870 | 1.0 | 440 | 54.5 | – | – | – | – |
| 2. | Forestry | 1.9 | 2.1 | 2.3 | 0.73 | 0.81 | 0.89 | 2.59 | – | 75.0* | 4,644 | 0.715 | 0.793 | 0.871 |
| 3. | Metal Mines | 460 | 509 | 660 | 126 | 139 | 153 | 3.66 | 13 | 9.4 | 8,301 | 69.0 | 76.121 | 83.788 |
| 4. | Fuels, Oil and Gas | 53 | 59.1 | 66 | 20.2 | 22.6 | 25.2 | 2.62 | 17.5 | 77.4 | 22,356 | 4.108 | 4.596 | 5.124 |
| 5. | Fuels, Coal | 3.0 | 3.4 | 4.0 | 1.14 | 1.29 | 1.52 | 2.64 | 1.17 | 90.7 | 1,026 | 5.051 | 5.716 | 6.735 |
| 6. | Nonmetal Mines | 110 | 124 | 140 | 49 | 55 | 63 | 2.24 | 12.3 | 22.4 | 2,547 | 87.456 | 98.165 | 112.443 |
| 7. | Food and Beverages | 150 | 168 | 185 | 106 | 118 | 130 | 1.42 | 9.5 | 8.1 | 35,866 | 13.435 | 14.956 | 16.477 |
| 8. | Tobacco | 1.8 | 2.1 | 2.4 | 0.28 | 0.33 | 0.38 | 6.36 | 0.08 | 24.2 | 1,371 | 0.928 | 1.094 | 1.260 |
| 9. | Rubber | 95 | 105 | 115 | 73 | 80 | 88 | 1.31 | 0.6 | 0.8 | 2,540 | 130.650 | 143.178 | 157.496 |
| 10. | Plastics | 150 | 164 | 180 | 115 | 125 | 137 | 1.31 | 0.9 | 0.7 | 2,680 | 195.067 | 212.029 | 232.384 |
| 11. | Leather | 1.2 | 1.28 | 1.35 | 1.09 | 1.16 | 1.23 | 1.10 | 0.08 | 6.9 | 1,329 | 3.728 | 3.968 | 4.207 |
| 12. | Textiles | 50 | 58 | 65 | 29 | 34 | 38 | 1.71 | 1.8 | 5.3 | 10,756 | 12.257 | 14.370 | 16.060 |
| 13. | Wood | 115 | 127 | 140 | 78 | 86 | 95 | 1.48 | 2.2 | 2.6 | 8,750 | 40.524 | 44.680 | 49.356 |
| 14. | Furniture | 0.53 | 0.59 | .65 | 0.38 | 0.42 | 0.46 | 1.40 | 0.12 | 28.6 | 2,666 | 0.648 | 0.716 | 0.784 |
| 15. | Paper, Mills | 2200 | 2453 | 2700 | 703 | 784 | 863 | 3.13 | 29 | 3.7 | 12,556 | 254.522 | 283.848 | 312.450 |
| 16. | Paper, Finishing | 290 | 316 | 340 | 94 | 102 | 110 | 3.10 | 3.7 | 3.6 | 4,202 | 101.693 | 110.348 | 119.003 |
| 17. | Printing | 16 | 17.8 | 20 | 1.25 | 1.39 | 1.56 | 12.81 | 0.04 | 2.9 | 6,523 | 0.871 | 0.969 | 1.087 |
| 18. | Iron, Mills | 430 | 481 | 520 | 172 | 192 | 212 | 2.50 | 8.1 | 4.2 | 7,281 | 107.389 | 119.876 | 132.363 |
| 19. | Iron, Foundaries | 95 | 104 | 115 | 38 | 42 | 46 | 2.50 | 1.7 | 4.0 | 1,740 | 99.278 | 109.729 | 120.179 |
| 20. | Other, Smelting | 300 | 335 | 370 | 185 | 207 | 228 | 1.62 | 6.7 | 3.2 | 4,476 | 187.889 | 210.233 | 231.561 |
| 21. | Other, Extruding | 130 | 144 | 160 | 80 | 88 | 98 | 1.63 | 2.9 | 3.3 | 2,345 | 155.084 | 170.593 | 189.978 |
| 22. | Metal Fabricating | 25 | 28 | 31 | 11 | 13 | 14 | 2.22 | 0.5 | 3.8 | 14,084 | 3.550 | 4.196 | 4.519 |
| 23. | Machinery | 67 | 74 | 81 | 3.76 | 4.16 | 4.55 | 1.78 | 2.55 | 61.3 | 10,361 | 1.650 | 1.825 | 1.996 |
| 24. | Transportation Equipment | 165 | 181 | 195 | 110 | 121 | 130 | 1.50 | 0.5 | 0.4 | 28,970 | 17.261 | 18.987 | 20.399 |
| 25. | Electrical Products | 35 | 37.3 | 40 | 12.9 | 13.7 | 14.7 | 2.72 | 0.31 | 2.3 | 9,966 | 5.884 | 6.249 | 6.705 |
| 26. | Nonmetallic Minerals | 70 | 78 | 90 | 36.5 | 40.6 | 46.9 | 1.92 | 4.0 | 9.9 | 5,445 | 30.473 | 33.896 | 39.156 |
| 27. | Petroleum Refineries | 450 | 496 | 550 | 210 | 232 | 257 | 2.14 | 11.8 | 5.1 | 20,662 | 46.203 | 51.043 | 56.543 |
| 28. | Petroleum and Coal Products | 48 | 53.1 | 58 | 22.5 | 24.9 | 27.2 | 2.13 | 1.26 | 5.1 | 168 | 811.769 | 898.358 | 981.339 |
| 29. | Chemicals, Industrial | 385 | 426 | 465 | 175.0 | 194 | 211 | 2.20 | 12.2 | 6.3 | 6,595 | 120.627 | 133.723 | 145.442 |
| 30. | Chemicals, Other | 840 | 937 | 1040 | 382 | 426 | 473 | 2.20 | 26.9 | 6.3 | 8,747 | 198.529 | 221.397 | 245.823 |
| 31.** | Misc Manufacturing | 9 | 10.1 | 11 | 4.3 | 4.8 | 5.2 | 2.10 | 0.53 | 11.0 | 5,145 | 3.799 | 4.241 | 4.595 |
| 32.** | Construction | | | | | | | | | | | | | |
| 33.** | Transportation | | | | | | | | | | | | | |
| 34.** | Electric Power | 2900 | 3220 | 3500 | 2900 | 3220 | 3500 | 1.00 | 35.8 | 1.1 | 9,159 | 1439.364 | 1598.191 | 1737.169 |
| 35.** | Other Utilities | | | | | | | | | | | | | |
| 36. | Trade | 245 | 269 | 295 | 245 | 269 | 295 | 1.00 | 5.8 | 2.2 | 184,208 | 6.046 | 6.638 | 7.280 |
| 37. | Other | | | | | | | | | | | | | |

* Estimate

**It is assumed that water required for these sectors is supplied through municipal water supplies.

# APPENDIX C

# WATER USES FOR ENERGY DEVELOPMENT

## APPENDIX C

## WATER USES FOR ENERGY DEVELOPMENT

In examining the impact of future energy-related developments in a subbasin, an estimate of their water use requirements is needed. These data are inserted into the model as part of the gauge basin data.

Phase I of this study documented the water use rates of energy projects and contained an extensive bibliography of other references. A table from that report, summarizing water consumption is reproduced as Table C.1.

TABLE C.1

CONSUMPTION OF WATER

| Process | Process Water Consumption: Standard Unit (product) | Process Water Consumption: Water Consumption $m^3$/Standard Unit (typical values) | Comment | Energy Development Water Requirements: Standard Production Rate (product) | Energy Development Water Requirements: Water Requirement $m^3$/s/Standard Production Rate (typical values) |
|---|---|---|---|---|---|
| Coal mining (surface and underground)* | tonnes | 0.01 - 0.06 (8)** | - | million t/yr | 0.0003 - 0.0019 |
| Coal mining (hydraulic)* | tonnes | 0.08 - 0.14 (2) | 15% makeup | million t/yr | 0.0025 - 0.0044 |
| Coal processing* | tonnes | 0.4 - 1.5 (8) | 10% makeup | million t/yr | 0.0127 - 0.0475 |
| Coal slurry pipelines | tonnes | 0.95 (37) | - | million t/yr | 0.0301 |
| Coal liquefaction | tonnes | 2.4 - 3.8 (9) | - | million t/yr | 0.0761 - 0.1204 |
| Tar sands extraction | bbl | 0.88 (9) | - | bbl/d | $1.02 \times 10^{-5}$ |
| Crude oil refining | bbl | 0.163 (10) | - | bbl/d | $1.88 \times 10^{-6}$ |
| Fossil fuel power plant | | | | | |
| - once-through cooling | $m^3$/s/1,000 MW | 32 - 78 (7) | - | MW | 0.00025 - 0.0015 |
| - cooling ponds | $m^3$/s/1,000 MW | 0.37 (7)<br>0.60 (7) | - | - | - |
| - forced evaporation | $m^3$/s/1,000 MW | 0.28 - 0.39 | - | - | - |
| Nuclear power plant | MW·h | 1.5 (13) | - | MW | 0.00043 |
| Uranium milling | | | | | |
| - Ontario and Newfoundland | kg | 0.67 (9) | low-grade ore | t/yr | $2.11 \times 10^{-5}$ |
| - Saskatchewan | kg | 0.4 (9) | high-grade ore | t/yr | $1.27 \times 10^{-5}$ |
| Methanol production (synthesis gas and biomass) | tonnes | 1.75 - 3.5 (2) | 14% - 25% makeup | t/d | $2.03 \times 10^{-5}$ - $4.05 \times 10^{-5}$ |

* Coal mining is divided into mining and coal processing. Therefore, to determine the water requirements of a coal mine operation, surface and underground mining or hydraulic mining values must be added to coal processing values, to determine the total water requirements of the development.

**Numbers in brackets indicate reference numbers in Reference section.